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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN No. 55.
B. T. GALLOWAY, *Chief of Bureau.*

THE
DRY ROT OF POTATOES
DUE TO FUSARIUM OXYSPORUM.

BY
ERWIN F. SMITH
AND
DEANE B. SWINGLE,
LABORATORY OF PLANT PATHOLOGY.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED FEBRUARY 16, 1904.

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BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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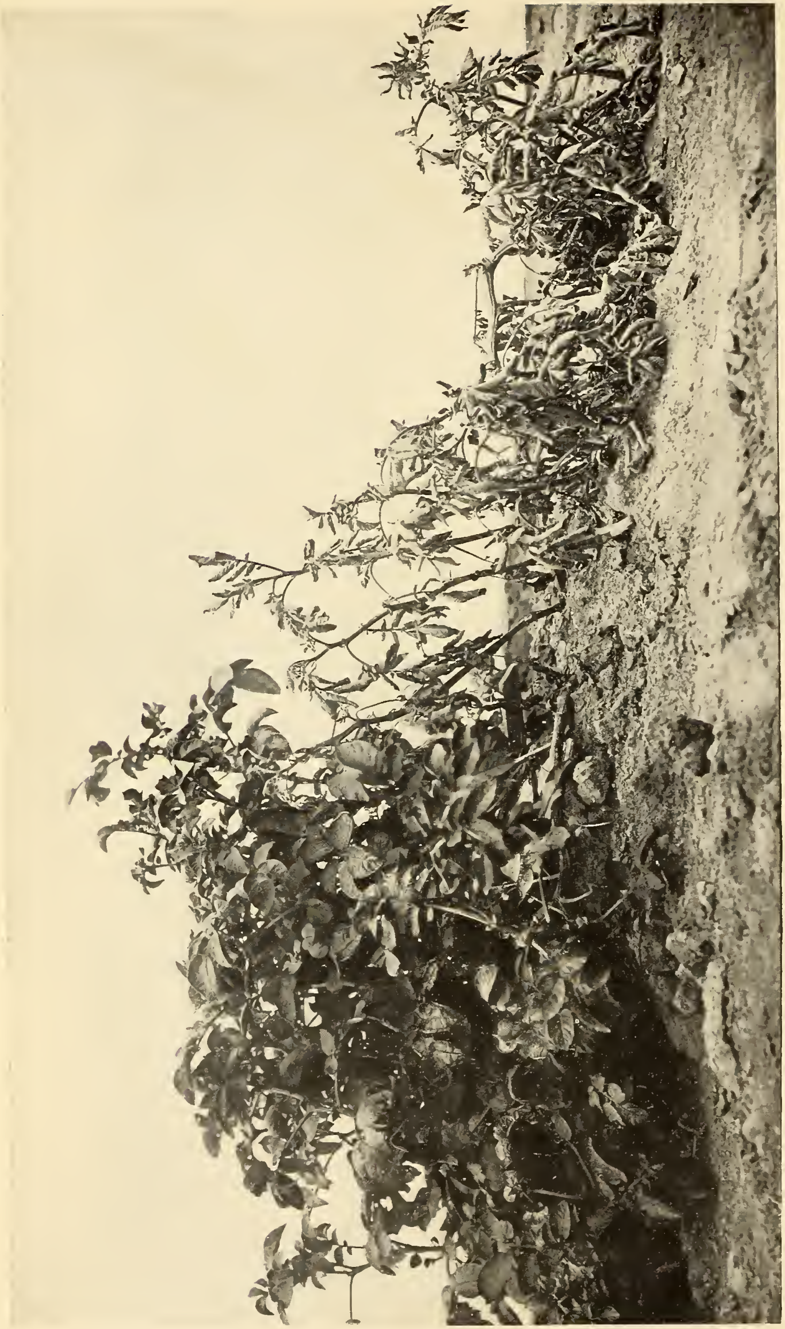

HILL OF POTATOES PARTLY DISEASED BY THE DRY-ROT FUNGUS (FUSARIUM).

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BUREAU OF PLANT INDUSTRY.

B. T. Galloway, *Chief.*

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[a] Detailed to the Bureau of Forestry.
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 7, 1903.

Sir: I have the honor to transmit herewith the manuscript of a technical paper on "The Dry Rot of Potatoes Due to Fusarium Oxysporum," by Erwin F. Smith, Pathologist, and Deane B. Swingle, Assistant in Pathology, Laboratory of Plant Pathology, Vegetable Pathological and Physiological Investigations, and recommend its publication as Bulletin No. 55 of the series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Studies on the widely prevalent dry rot of the potato have been carried on in the Laboratory of Plant Pathology in this Department for some years. It is now believed that the cause has been discovered, together with a method of storing diseased tubers which will reduce the winter loss to a minimum.

The results of the field experiments showed that the use of ordinary fertilizers, while favoring the growth of the potato, did not tend to make the plants resistant to the disease. It was observed, however, that some hills were more resistant to the disease than others, and it is believed that by the continued selection of resistant plants in badly diseased fields a hardy strain of potatoes can be obtained, and an effort will be made to do this. The bulletin also points out the fact that many fields are already permanently seeded down to the organism which causes this disease, and methods are suggested for avoiding the extension of the disease to uninfected fields.

A number of interesting points in the life history of the fungus have also been worked out. Whether this disease is identical with the "sleepy disease" of tomatoes, as the writers think probable, remains to be determined by cross inoculations.

Albert F. Woods,
Pathologist and Physiologist.

Office of Vegetable Pathological and
Physiological Investigations,
Washington, D. C., December 5, 1903.

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THE DRY ROT OF POTATOES DUE TO FUSARIUM OXYSPORUM.

INTRODUCTION.

Dry rot of the potato has long been known both in this country and abroad, but the real cause of the trouble was little understood until recent years, the first work of importance having been done in Germany.

Undoubtedly a number of diseases due to very different causes have been included under this name in different sections of this country, but there is no doubt that the disease here described has been for many years one of the chief causes of dry rot. Potato troubles characterized by browning of the flesh have been recorded by numerous workers, but the descriptions have been for the most part so incomplete that it is in nearly all cases quite impossible to say whether the diseases described were identical with this or not.

In Illinois, Clinton observed "bundle blackening" and "dry end-rot," but does not appear to have found these diseases serious or to have connected either of them with conditions originating in the field. Of the first, he says:

> This is a fungous trouble of stored potatoes. * * * The fungus gains entrance probably after the potatoes are gathered, through the dead stem, and proceeds from this through the bundles, causing them to turn black as a result of the attack. While not a very serious malady, it is objectionable, as it opens the way for other fungi and bacteria so that often tissue in the neighborhood of the affected bundles becomes diseased and a general rotting is started. It may also cause a slight waste and some trouble in cleaning potatoes for use. The fungus is quite similar to the one causing the following trouble [dry end-rot].

Of the latter, he says: "As in the preceding case, the trouble begins at the stem end, the fungus gaining entrance after the rupture of the tuber from the plant." This disease is correctly ascribed to *Fusarium solani*, and storage of the tubers in a dry, cool place is recommended.

Stewart, under the title "Another stem-blight of potatoes," has very briefly described a disease that is also probably the same, although in a second bulletin he makes the following statements:[a]

> The potato stem-blight herein discussed is the one discribed by the writer in Bulletin No. 101 of this station, pages 83–84. The symptoms of the disease, as there given, are as follows: "First, there is a cessation of growth. The topmost leaves take on a yellowish, or, in some cases, a purple color, and roll inward from the edges upward, exposing the under surfaces. This condition is followed by wilting and complete drying up of the entire foliage, the process taking from one to three weeks. The tubers appear to be sound, but, when cut at the stem end, blackened fibers are seen penetrating the flesh to a considerable distance, materially injuring it for cooking purposes. No rot develops in the tubers. The stem just beneath the surface of the soil first shows discolored spots and later becomes dry and shriveled."
>
> This disease has continued to be destructive in 1896 and 1897, but the cause of it is still unknown. Formerly a species of Oospora was suspected of having some connection with it, but it is now very doubtful if any organism is responsible for the trouble. The portion of the stem which is below ground is quite evidently the seat of the disease, but no fungus hyphæ can be found in the tissues of this part of the plant in the early stages of the disease; neither are bacteria abundant, and the few which are found in the tissues may easily have gained entrance after the death of the stem. Numerous petri dish cultures of tissue from the interior of diseased stems were made with varying results.

The best work has been done in Germany. Wehmer has given a very interesting account of inoculation experiments with a *Fusarium* called *F. solani*. He found that this *Fusarium* may enter through a fresh wound if either spores or pieces of potato affected with the same disease be placed on the raw surface; also that in some cases contact rot may take place through the unbroken skin if a mass of the actively growing mycelium be placed on it. He entirely misses, however, the very important fact that normally in the field the fungus enters the tuber through the underground stem. Indeed, all of his experiments appear to have been made on tubers in the laboratory. After the fungus has entered, Wehmer finds that it destroys the tubers without the aid of bacteria, and that keeping them in dry air does not seriously retard its action. Wehmer was the first to clearly demonstrate the infectious nature of this fungus. Sorauer observed this disease or a similar one in the field, and believed *Fusarium* to be the cause, but did not demonstrate it. De Bary and others considered the fungus as purely saprophytic.

Fusarium on decaying potato tubers has been a familiar sight to the senior writer ever since he began to be interested in plant pathology, but until recently always associated with other fungi or with bacteria. Dry rot of potatoes as a distinct disease caused by *Fusarium* first came to his notice in October, 1899, when two barrels of tubers were received by him from Hubbardston, Mich. They were a very fine lot and apparently sound when received, the disease not having progressed to a noticeable extent at that time. They were stored in barrels in a warm, dry cellar, where there was plenty of light. Two months later (December 10) they were examined. A very few were entirely shriveled and dry, and specked on the surface with tufts of white fungus. Very many more were partly affected, the diseased portion in all cases except five or six being at the basal end. Only three of the entire lot showed soft bacterial rot. All the diseased tubers except these three showed a blackening in the vascular ring and other characters described later in this paper. The potatoes were of two varieties—Carman, and another that was not determined but which was neither Early Rose nor Burbank. They were grown from tubers obtained somewhere in the East. Both varieties were affected with the disease. Other potatoes of these two varieties grown in the same field, but stored in a cool, damp cellar in Michigan, were not seriously injured by the disease. Examined in midwinter it was with difficulty that any cases could be found. In almost every instance the black stain remained confined to a very small region around the stem, and did not materially lessen the value of the potatoes. Inquiries of the housewife also showed that disagreeable black places, so common in the badly affected tubers, had not been found in the cooked tubers.

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[a] Stewart in Bul. No. 138, N. Y. Agr. Exp. Station, Geneva, N. Y.

Most of the potatoes in which this disease was studied were raised on the Potomac Flats, Washington, D. C., in the summer of 1902. Three varieties were planted—Burbank, Early Rose, and an unknown variety, designated for convenience, owing to certain characters, as "Brown." They were planted April 16, 1902, in rows both ways, in 24 large plots and 6 smaller ones, the larger plots having 5 rows of 20 hills each and the smaller ones 5 rows of 5 hills each. The hills were 3 feet apart each way and the distance between the plots was 4½ feet. The land used was a rich sandy loam (dredged river mud) that had been planted to watermelons the year before. It was nearly level, having only a very gradual slope to the southeast. There was a plantation road on two sides of the patch.

The following fertilizers were used: Freshly slaked lime, dissolved boneblack (16 to 18 per cent phosphoric acid), nitrate of soda, muriate of potash, and sulphate of potash. Exclusive of the "Browns," four large plots were devoted to each fertilizer, two receiving heavy doses and two moderate doses. Burbanks were planted on one of the heavily treated plots, and Early Rose on the other. The same varieties were planted on the lightly treated plots. Of those fertilized with lime, two plots received 25 grams and two 75 grams to the hill. Of the other fertilizers the amounts used were 8 grams and 16 grams to the hill for these two varieties. For the "Browns," which were in the smaller plots, only one amount of each fertilizer (the larger) was used. There were two check plots containing no fertilizer for the Burbanks, two for the Early Rose, and one for the "Browns." The fertilizer was dropped in the furrow and mixed well with earth, and on this the potato was dropped and covered with a hoe. In the case of the Burbanks and Early Rose only very clean, healthy-looking tubers were planted, and all but the smallest of these were cut longitudinally into two or four pieces, depending on the size. The "Browns" were affected with the "brown specking" described later, and were all cut in two.

Very marked differences were shown in the size, vigor, color, and habits of growth of the vines in the different plots, but that is a matter that need not be discussed here, the experiment being planned for quite a different purpose, viz, to check up Laurent's work on bacterial soft rot of the potato.

During the course of the season many of the shoots in all the larger plots were inoculated near the top by hypodermic injection with *Bacillus coli* and various other bacteria, but most of these inoculations (all of *B. coli*) had no more effect than would be caused by injecting the same quantity of water, and seldom was there any more serious result than a blackening of one side of the stem for a few centimeters below the wound. These inoculations can not be considered, therefore, as having had any influence on the progress of the *Fusarium* disease.

The disease began to show its effect on the foliage of a few hills about July 1, and by the middle of July it was quite noticeable on many of the plants. It did not seem to spread from centers of infection, but very frequently hills would be attacked that were entirely surrounded by healthy plants. There was little evidence that the disease spread from plant to plant through the soil. More and more plants continued to be attacked by the disease until the vines and tubers had completed their growth. From the fact that at the time the potatoes were harvested a very large per cent of them was affected, at least slightly, it would seem that the entire soil must have been infested with the fungus. There was very little soft bacterial rot and only a moderate amount of potato scab.

All of the "Browns" in the smaller plots were saved and about one and one-half bushels from each of the larger plots of Burbanks and Early Rose. They were put in canvas grain bags and stored in one pile in a rather warm, dry basement. There were 30 bags in all. The pile was made by laying one tier down on their sides and laying other tiers on top, and when complete was about twice as long as high. One end of each bag was against a board partition and the other exposed to the air. On top of the pile a few bags of cotton bolls were placed. This kept all the bags under about the same conditions of moisture. The bags being closely woven, the atmosphere between the tubers inside was very humid.

The potatoes were cut up and examined late in February and notes made on each individual tuber. The results of this examination will be given later in this paper.

EFFECT OF THE DISEASE ON THE PLANTS.

The disease ordinarily enters the plant through the roots and slowly spreads until the whole root system, a few centimeters of the lower part of the stem, the underground stems bearing the tubers, and the tubers themselves are invaded by the fungus.

The disease first becomes noticeable when the plants are about a foot high. The first indication to the casual observer that the plants are affected is a change in the appearance of the leaves. These assume a somewhat lighter green color than those of healthy plants, though they do not for a considerable time become decidedly yellow or brown. Along with this change in color the leaves lose to some extent their bright glistening appearance and look duller, and early begin to curl and roll up (Pls. I and II). Those that have not reached their full growth when the plant is attacked are somewhat dwarfed in size. The effect on the leaves does not, however, seem to be sufficient to stop or very seriously impair their work, and there is every evidence that in the first stages of the disease photosynthesis and respiration go on in a normal manner.

The stems above the ground do not show any evidence of being affected in the early stages of the disease. The color is normal, and there is no shrinkage; neither is there wilting of the shoots or leaves for several weeks after the disease begins. When the plants reach maturity the diseased vines that were attacked early are noticeably shorter than the sound ones. As the disease progresses the roots become so weakened that they can no longer hold the stems erect, and the latter, therefore, become prostrate in a manner that is very noticeable (Pl. III). This is especially the case if the earth has not been hilled up around the stems. Usually all the shoots in the same hill are affected, but such is not always the case, for not infrequently in the later stages some will be erect and to every appearance healthy while others have fallen down and have all the symptoms described above (Pl. I).

When the plants have reached this condition they can be pulled up with much greater ease than healthy ones, and an examination shows that all the smaller roots are so friable that they can be broken with almost no effort, and some can even be rubbed to pieces between the thumb and finger. The main root also is much more tender and brittle than that of healthy plants, and this condition extends nearly to the line marked by the surface of the ground.

Such diseased roots are usually covered with a white, pink, or even reddish growth of mycelium, which is distributed very unevenly and is much more conspicuous in some places than in others. Microscopical examination shows that this mycelium invades all parts of the root, though the bark is most affected. It is present in the water ducts, but it is not especially abundant there, as it is in the wilt disease of the watermelon, for example. The conidia are not formed in the early stages of the disease, and up to the time the potato stems have fallen over on the ground there are comparatively few. No perithecia and none of the mature sickle-shaped spores (macroconidia) characteristic of *Fusarium* were found on the roots of living vines. The mycelium does not extend up into the stems and leaves. Sections cut at the surface of the ground showed only very few hyphæ or none at all. There was, however, a marked browning of the tissues, particularly of the vascular ring. This browning usually extends only a few centimeters above the surface of the ground. The underground stems on which the tubers are borne are nearly always attacked, but they do not as a rule become so soft and brittle as roots of the same size. The mycelium passes through the whole extent of these underground stems into the base of the tubers. A detailed account of the effect of the fungus on the tubers will be given later.

As soon as the roots become so badly affected that they can no longer take up water and nourishment from the soil, a very marked change takes place in the leaves and stems. Up to this time, as has been previously stated, there is no wilting, but, now that the water supply is cut off, the foliage and the upper part of the shoots begin to droop and become flabby, and soon die and turn dark brown. Fortunately, the tubers have in most cases become ripe or nearly so (though usually prematurely), so that the crop from the diseased hills is not entirely destroyed.

In case the plants are not attacked until the stems and leaves have nearly reached maturity, the early symptoms of curling and dwarfing of the foliage do not appear. Even in such cases, however, if the roots are entirely destroyed before the tops have died down there are the later symptoms of wilting, but often the fungus grows into the tubers without causing any visible symptoms in the parts above ground.

As stated above, the fungus usually enters the tubers through the underground stems, though it occasionally gets in through wounds. As the tubers are so well protected from injuries by the surrounding earth the damage done by the disease entering in this way would necessarily be small.[a] Tubers examined much before the time of ripening were often found to contain the fungus at the basal end, showing that they may be affected while yet very immature, though there is little evidence that the growth of the tuber is thereby seriously checked. At the time the potatoes were harvested a very large proportion of those examined were found to be slightly affected, though the disease rarely extended into the potato more than three or four centimeters, and usually much less. At this time the disease was confined to the basal part of the vascular ring and appeared as a cinnamon-brown stain extending inward irregularly, farther in some places than in others. There was very seldom any soft rot in those examined while they were being harvested, and the flesh inside and outside the vascular ring was white and perfectly normal as far as could be determined.

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[a] Except, perhaps, in continued wet weather. See footnote, p. 53.

Tubers of all sizes are attacked. The fungus was often found in those not more than two centimeters in diameter, though probably a higher per cent of the large ones than of the small ones are diseased.

While the potatoes are in storage the fungus progresses inward farther and farther, at first following the vascular ring. This ring gradually changes from cinnamon-brown to nearly black in the parts affected. The discoloration becomes visible in the ring as fast as the hyphæ progress inward—at least the threads were never found in advance of the blackened part. The blackening does not, however, precede the advance of the fungus, as microscopical examination never failed to show threads in the most newly blackened parts, and numerous cultures made from the extreme ends of the discolored portions of the bundles very seldom failed to develop the fungus.

These cultures were made by carefully paring especially favorable pieces of diseased tubers with a hot scalpel, heating it nearly to redness before each stroke and cutting out pieces a few millimeters in diameter, containing a length of about two millimeters of the extreme end of the discolored part of the bundle. These pieces were cut from the main part of the specimen with the hot scalpel and allowed to drop directly into a tube of sterile culture media. Potato cylinders were used principally for media. Slant tubes of beef agar (+15 on Fuller's scale) also were sometimes used. One hundred and twenty-two cultures on potato and sixteen on agar were made, and in all but two cases on the potato and in every case on the agar the fungus appeared after a day or two as a white mycelium, sparse at first, growing directly out from the blackened bundles and spreading into the media. Forty-two cultures on potato and four on agar were also made from older parts of the discolored ring nearer the basal end, and of these all but one on the potato and all on the agar produced a growth of the fungus. Bacteria sometimes appeared in the cultures along with the fungus, and this was especially noticeable in those tubes in which the fungus did not come out, and was doubtless what kept the mycelium from developing further. These bacteria were probably, in many cases at least, intruders that got in while the cultures were being made. In other cases they probably developed from rods which entered the potato along with the fungus and did not find conditions favorable for growth until the fragments of potato were put into our culture tubes. In making a large number of cultures it is impossible to avoid occasional air-borne contaminations, but long experience has shown that in general we get in our cultures only what we put into them.

The fungus pushes its mycelium farther and farther into the vascular system until it has reached entirely to the eye end unless progress is interrupted by some change in the condition of the tubers.

The surface of the potato remains perfectly sound and normal during the early stages. Sometimes, indeed, the vascular ring is blackened throughout its entire extent before there is any external indication that the disease is present. Such potatoes might pass in the market, and as a matter of fact often do pass, as perfectly sound and healthy until cut open and examined. They are, however, quite unfit for use. Many such come into the Washington market every year.

If the diseased tubers be cut crosswise this ring may be seen to be blackened either continuously all the way around or in only a few isolated places (Pls. IV and V). Sometimes there is only a single dark band a few millimeters wide running through the tuber in the vascular system from end to end. A tangential section of the blackened ring shows that the color is much darker in some ducts than in others, giving it a veined or netted appearance. The thickness of the black ring is only very slight—seldom more than 1 or 2 millimeters.

As stated above, the flesh inside and outside the dark ring is at first white and apparently normal. After a time, however, a yellowish stain appears in places in that part of the flesh closest to the ring, either in the inner or the outer portion, and the fungus slowly spreads into these discolored portions. The discoloration seems, however, to keep a little distance in advance of the fungus, as no mycelium could be found with the microscope in the distal part of the yellow regions, nor did cultures made from such parts give any fungous growth. This process of discoloration, followed by the invasion of the mycelium, continues until, in many cases, the entire tuber is affected. If there is a cavity inside the tuber the fungus usually penetrates it and appears as a dense white growth (Pl. V often bearing conidia. The hyphæ that push from the ring out toward the periphery break through the skin and first appear as a white growth on the surface. Whether or not these hyphæ ever bore directly through the cells of the skin is difficult to determine. It is certain, however, that they often break out through very tiny ruptures that seem to be the lenticels. More frequently the tubers are so shrunken by the time the fungus gets to the periphery that the skin folds and cracks, and the mycelium grows out through these openings in great abundance, appearing on the surface as dense white or gray-white tufts (Pl. VI). These soon bear small oval microconidia, and later the curved, septate macroconidia characteristic of the form-genus *Fusarium*. Occasionally, also, if the surface of the potatoes is kept moist, a compact, wart-like stroma, a few millimeters in diameter, is formed. Microscopical examination shows that this is made up almost entirely of a dense mass of chlamydospores. Perithecia were never found on any of the tubers. The formation of tufts on the surface seems to be favored by a moist atmosphere, as this phenomenon was much more common on the crop of 1902 stored in bags than on those received from Michigan and kept in open barrels. The appearance of the latter is shown in Plate VI, the shriveled tubers being very dry and hard, and many of them free from surface mycelium.

Along with the general discoloration of the flesh there is a very decided shrinkage of the tubers. This causes the skin to become wrinkled in the form of concentric rings about the stem end. If bacterial decay does not set in, the rot becomes drier and drier and the flesh turns darker and darker, the vascular ring, however, continuing to be the darkest, until the tuber is brown, dry, very light in weight, and often nearly as hard as wood, having a very characteristic musty odor entirely different from that of the bacterial decay.

The starch grains do not seem to be corroded by the action of the fungus, at least not promptly. In some tubers that were completely dry and shriveled the grains were notched over the entire surface, but in such cases there was probably a mixed infection of fungus and bacteria. Other fungi also may have been present as saprophytes. In tubers where the yellowing extended throughout only part of the flesh, starch grains were found in a tangled mass of the mycelium without any marks of corrosion. These grains were being acted upon by the fungus, however, for they stained purple with the iodine test, instead of blue, as do normal grains.

Though the fungus usually enters the tuber by way of the underground stem, in some cases it had clearly got in through wounds. Sometimes there would be two separate infections—one through the basal end, with a limited browning in the vascular ring, and the other through a wound in the side or the apical end. Often these two diseased regions would be separated by entirely sound white flesh. There were a few other cases where the tubers were infected through apparently unbroken skin by contact with diseased neighbors having tufts of white mycelium on their surfaces, but these cases were rare.

When the fungus has once gained entrance it spreads without any visible mechanical obstruction to its progress. Whether or not the cells produce any chemical substances that tend to check its progress has not been determined, but no corky layer is built between the diseased and the sound portions. The hyphæ sometimes go between the cells of the parenchyma for a short distance, but in most cases they penetrate the cell walls and ramify between the starch grains, apparently absorbing the protoplasmic contents and dissolving and assimilating parts of the grains themselves. Those hyphæ that follow the xylem ducts do not form a dense mass, filling the tuber, but push forward with little branching (Pl. VIII, fig. 34). A few small microconidia have been found in the ducts, but none of the septate, curved macroconidia.

The potatoes from Michigan stored in a very dry place were very little affected by other fungi or by bacteria. In the case of those raised in Washington and stored in bags, which kept them somewhat moist, several other fungi appeared, particularly *Stysanus stemonites* and *Acrostalagmus cinnabarinus*, in the cavities of those that were entirely dead and often worm eaten, and *Penicillium* and *Aspergillus* on the surface. None of these appeared to be true parasites, however, as they were always accompanied by either the *Fusarium* or a bacterial decay. More or less soft bacterial decay was present in all the bags, but this seemed for the most part only secondary, though the bacteria were often to be found in the blackened ring. In such cases they did not, when the flesh bounding the ring was white and sound, penetrate as far as the mycelium, as shown by microscopical examination and by the fact that poured agar plates from the most advanced part of the black-stained portion of the ring gave pure cultures of the fungus. When the bacteria were sufficiently vigorous in their attack they produced various kinds of soft rot, usually very vile smelling, that often consumed the entire tuber except the skin, which is very resistant to their action and also to that of the fungus. The bacteria, like the fungus, entered as a rule through the stem end, though there was occasionally a case of contact rot at the side, or the apical end, or in the vicinity of a wound. On the surface of the bags and on dead stems in the field two pyrenomycetous fungi were found, viz, *Melanospora ornata* and *Nectria brassicæ*, but neither could be connected with the disease. Mycelium cultivated from the ascospores of these two species grew badly on various media in which the *Fusarium* grew luxuriantly, and looked quite different.

In cases where there was a mixed infection of fungus and bacteria the black bundles could often be followed for long distances through the whitish macerated flesh, an indication that the infection by *Fusarium* had preceded the bacterial decay.

When examined in February most of the tubers, especially the Early Rose, bore sprouts several centimeters long, and these were often killed and blackened by contact rot, and sometimes even bore tufts of the fungus.

Another complication that was found in some of the tubers was a brown specking in the flesh. This specking is not confined to the vicinity of the vascular ring, though usually more prevalent there, but may be found in any part of the tuber, noticeably in the stem end, where it seems to originate. There may be specked regions entirely isolated and surrounded by white flesh, though such is not usually the case. Whether or not the *Fusarium* fungus is the primary cause of this trouble has not yet been determined. Microscopical examination, however, shows neither fungi nor bacteria. Cultures of the brown-specked tissue made by cutting out pieces with a hot scalpel in the manner previously described did not, as a rule, develop any fungous mycelium. When this did appear it was almost invariably the *Fusarium* and was probably the result of a complication of the two troubles. Bacteria sometimes appeared in these cultures, but these were of such varied kinds and were so often absent that it seems probable that they accidentally got in when the cultures were being made. The brown specking may be due to a parasite—perhaps the *Fusarium*—but in any case the discolored regions themselves seem not to be infested.

EFFECT OF DIFFERENT FERTILIZERS ON RESISTANCE TO THE DISEASE.

For the purpose of determining whether or not the different fertilizers added to the soil in the several plots had any effect on the resistance of the potatoes to the attack of the fungus, the tubers that were stored in bags during the winter were examined about the last of February and a careful comparative series of notes was made. All the tubers were cut, and the extent and nature of the disease recorded for each individual separately; also the condition of the fungus and the extent to which other fungi and bacteria were present, as well as any other points of special interest in connection with the disease. From this enormous mass of notes tabulations were made, and these were condensed into the first four tables that appear in the text.

Several things must be taken into consideration in judging which of a number of individuals is the most resistant to the attack of any specific disease. In the case of this potato disease the most important of these are, first, resistance to the entrance of the fungus; second, ability to check the spread of the fungus after it has gained entrance; third, ability to keep the fungus from forming spores; and, fourth, ability to keep some part of the tuber alive until time for renewed growth the following season. Unfortunately, in the case of those examined there was in so many instances bacterial action during the latest stages of destruction that whether or not any particular tuber remained alive when examined did not depend simply on resistance to the fungus alone. Whether or not there was total destruction caused by the *Fusarium* could not then in many cases be determined, and therefore does not appear in the tables.

TABLE I.—*Percentage of tubers diseased by Fusarium, according to plot, variety, and fertilizer used.*

Plot.	Variety.	Fertilizer.		Percentage of stored tubers diseased in February.
		Kind.	Amount per hill.	
			Grams.	
2042	Burbank	Boneblack	8	98.6
2045	do	Sulphate of potash	16	98.0
2055	do	Muriate of potash	16	97.2
2054	Early Rose	do	16	95.4
2034	do	Lime	75	94.4
2060	Burbank	Check		94.1
2037	do	Lime	25	93.3
2047	do	Boneblack	16	93.2
2040	do	Sulphate of potash	8	92.9
2052	do	Nitrate of soda	8	92.7
2053	Brown	Sulphate of potash	16	92.3
2058	do	Nitrate of soda	16	91.8
2061	Early Rose	Check		91.5
2059	do	do		91.0
2046	do	Boneblack	16	90.1
2050	Burbank	Muriate of potash	8	90.0
2044	Early Rose	Sulphate of potash	16	89.3
2036	do	Lime	25	88.2
2041	do	Boneblack	8	87.9
2035	Burbank	Lime	75	87.9
2049	Early Rose	Muriate of potash	8	87.5
2051	do	Nitrate of soda	8	87.5
2048	Brown	Muriate of potash	16	87.1
2062	Burbank	Check		84.8
2056	Early Rose	Nitrate of soda	16	83.2
2039	do	Sulphate of potash	8	82.8
2043	Brown	Boneblack	16	82.1
2063	do	Check		78.1
2038	do	Lime	75	75.1
2057	Burbank	Nitrate of soda	16	74.7

Table I shows the percentage of tubers diseased in each plot, whether very seriously or only slightly. It will be seen that the plots are arranged in order of percentage affected, the worst being at the head of the list. Those that are most resistant to the entrance of the fungus would, then, other conditions being equal, be at the end.

TABLE II.—*Percentage of tubers wholly affected with Fusarium in February, 1903, by plot, variety, and fertilizer.*

Plot.	Variety.	Fertilizer.		Wholly affected.
		Kind.	Amount per hill.	
			Grams.	
2040	Burbank	Sulphate of potash	8	49.7
2042	do	Boneblack	8	30.8
2060	do	Check		30.2
2043	Brown	Boneblack	16	27.4
2055	Burbank	Muriate of potash	16	25.4
2049	Early Rose	do	8	24.2
2045	Burbank	Sulphate of potash	16	22.3
2053	Brown	do	16	22.1
2035	Burbank	Lime	75	19.7
2046	Early Rose	Boneblack	16	16.6
2054	do	Muriate of potash	16	15.4
2061	do	Check		15.3
2037	Burbank	Lime	25	15.1
2050	do	Muriate of potash	8	14.6
2051	Early Rose	Nitrate of soda	8	13.3
2048	Brown	Muriate of potash	16	13.0
2047	Burbank	Boneblack	16	12.8
2063	Brown	Check		10.9
2056	Early Rose	Nitrate of soda	16	10.5
2039	do	Sulphate of potash	8	10.4

Table II.—*Percentage of tubers wholly affected with Fusarium in February, 1903, by plot, variety, and fertilizer*—Continued.

Plot.	Variety.	Fertilizer.		Wholly affected.
		Kind.	Amount per hill.	
			Grams.	
2034	Early Rose	Lime	75	9.9
2038	Brown	....do	75	9.8
2051	Early Rose	Nitrate of soda	8	9.8
2062	Burbank	Check		9.7
2059	Early Rose	....do		9.1
2036	....do	Lime	25	6.5
2044	....do	Sulphate of potash	16	6.1
2057	Burbank	Nitrate of soda	16	5.6
2058	Brown	....do	16	4.9
2041	Early Rose	Boneblack	8	2.1

Table II shows the percentage of tubers in which the browning of the vascular system has reached practically to the apical end. This does not mean necessarily that it is completely rotted, for in some cases there is sound white flesh inside and outside the ring, especially at the apical end; while in others, in which the blackening does not reach entirely through the potato, it is affected throughout by a semisoft rot, partly bacterial. A large majority of the tubers recorded in this table are, however, completely dry-rotted by the fungus. Like Table I, the plots are arranged in order, the highest percentage being at the top.

Table III.—*Percentage of tubers showing tufts of mycelium, by plots, variety, and fertilizer.*

Plot.	Variety.	Fertilizer.		Percentage of tubers showing tufts of mycelium in February.
		Kind.	Amount per hill.	
			Grams.	
2045	Burbank	Sulphate of potash	16	67.6
2053	Brown	....do	16	53.8
2048	....do	Muriate of potash	16	48.1
2040	Burbank	Sulphate of potash	8	45.4
2042	....do	Boneblack	8	44.0
2050	....do	Muriate of potash	8	42.7
2055	....do	....do	16	42.7
2037	....do	Lime	25	42.4
2038	Brown	....do	75	40.5
2063	....do	Check		38.4
2060	Burbank	....do		36.7
2034	Early Rose	Lime	75	32.9
2039	....do	Sulphate of potash	8	29.4
2054	....do	Muriate of potash	16	29.0
2049	....do	....do	8	28.1
2035	Burbank	Lime	75	28.0
2047	....do	Boneblack	16	26.3
2041	Early Rose	....do	8	25.7
2059	....do	Check		25.1
2046	....do	Boneblack	16	25.1
2058	Brown	Nitrate of soda	16	22.9
2043	....do	Boneblack	16	21.9
2052	Burbank	Nitrate of soda	8	18.7
2062	....do	Check		18.4
2061	Early Rose	....do		15.3
2056	....do	Nitrate of soda	16	15.1
2036	....do	Lime	25	13.7
2044	....do	Sulphate of potash	16	11.2
2051	....do	Nitrate of soda	8	8.3
2057	Burbank	....do	16	7.8

In Table III is represented the percentage in each plot showing white fungous tufts, either in cavities or on the surface. This represents the extent to which the fungus has formed spores, for while there are sometimes microconidia borne on the hyphæ in the blackened ring, they are very few in number; whereas, on the other hand, the white tufts nearly always bear them, usually in great abundance. This table is likewise arranged in order of percentage.

TABLE IV.—*Giving number of tubers examined and extent of disease in per cents, by plot, variety, and fertilizer, in February, 1903.*[a]

Plot.	Variety.	Fertilizer.		Number examined.	Sound.	Doubtful.	Diseased with Fusarium.	Slight.	Less than half.	Half.	More than half.	Nearly all.	All.	Tufts of mycelium present.
		Kind.	Amount. *Grams.*											
2041	Early Rose	Boneblack	8	140	11.4	0.7	87.9	40.7	18.6	6.4	11.4	7.9	2.1	25.7
2042	Burbank	do	8	143	.0	1.4	98.6	19.6	17.5	9.8	13.3	7.7	30.8	44.0
2046	Early Rose	do	16	151	9.9	.0	90.1	29.1	13.2	9.9	14.5	6.6	16.6	25.1
2047	Burbank	do	16	266	6.4	.4	93.2	39.1	12.0	6.8	10.9	11.3	12.8	26.3
2043	Brown	do	16	146	15.8	2.1	82.1	19.9	10.9	4.8	10.3	8.9	27.4	21.9
2036	Early Rose	Lime	25	153	11.8	.0	88.2	45.1	18.9	10.5	4.5	2.6	6.5	13.7
2037	Burbank	do	25	165	5.5	1.2	93.3	19.4	21.2	10.3	19.4	7.9	15.1	42.4
2034	Early Rose	do	75	213	4.7	.9	94.4	29.1	25.4	12.2	13.1	4.7	9.9	32.9
2035	Burbank	do	75	157	7.0	5.1	87.9	21.0	15.3	5.1	14.7	12.1	19.7	28.0
2038	Brown	do	75	173	8.7	16.2	75.1	19.1	31.8	5.8	5.8	3.5	9.8	40.5
2039	Early Rose	Sulphate of potash.	8	221	8.1	9.1	82.8	24.4	19.5	10.9	9.9	7.7	10.4	29.4
2040	Burbank	do	8	141	.0	7.1	92.9	12.8	6.4	7.8	8.5	7.8	49.7	45.4
2044	Early Rose	do	16	196	10.7	.0	89.3	33.7	20.4	12.8	11.7	4.6	6.1	11.2
2045	Burbank	do	16	148	.0	2.0	98.0	12.8	28.4	3.4	21.6	9.4	22.3	67.6
2053	Brown	do	16	104	.0	7.7	92.3	26.9	14.4	.0	19.2	9.6	22.1	53.8
2049	Early Rose	Muriate of potash.	8	128	7.0	5.5	87.5	18.7	12.5	14.8	10.9	6.3	24.2	28.1
2050	Burbank	do	8	199	1.0	9.0	90.0	11.1	23.1	8.5	23.6	90.0	14.6	42.7
2054	Early Rose	do	16	162	3.1	1.2	95.4	30.9	24.7	5.5	11.1	8.0	15.4	29.0
2055	Burbank	do	16	138	1.4	.7	97.2	31.9	7.2	10.1	9.4	13.8	25.4	42.7
2048	Brown	do	16	108	8.3	4.6	87.1	25.0	18.5	5.5	16.7	7.4	13.0	48.1
2051	Early Rose	Nitrate of soda.	8	144	12.5	.0	87.5	36.1	21.5	11.1	6.2	2.8	9.8	8.3
2052	Burbank	do	8	150	7.3	.0	92.7	36.0	18.7	8.7	8.7	7.3	13.3	18.7
2056	Early Rose	do	16	172	8.1	8.7	83.2	29.1	19.8	8.7	11.0	4.1	10.5	15.1
2057	Burbank	do	16	178	12.9	12.4	74.7	47.8	11.1	6.2	2.8	1.1	5.6	7.8
2058	Brown	do	16	61	.0	8.2	91.8	34.4	29.5	4.9	13.1	4.9	4.9	22.9
2059	Early Rose	Check		276	6.5	2.5	91.0	31.9	13.8	8.7	15.6	11.9	9.1	25.1
2060	Burbank	do		169	1.8	4.1	94.1	21.9	13.6	5.3	17.2	5.9	30.2	36.7
2061	Early Rose	do		189	6.9	1.6	91.5	33.3	18.5	11.6	5.8	6.9	15.3	15.3
2062	Burbank	do		185	7.6	7.6	84.8	37.3	16.2	5.4	7.0	9.2	9.7	18.4
2063	Brown	do		146	10.3	11.6	78.1	16.4	29.4	4.8	14.6	2.1	10.9	38.4

[a] See fig. 1, p. 23.

In Table IV we have recorded all the chief points of interest covered by the notes taken when the potatoes were examined. "Number examined" includes all that were stored during the winter and examined in February. In the larger plots there were so many that not all were saved at harvest time. "Sound" includes all that were certainly not affected with the *Fusarium* disease. "Doubtful" includes all those so affected, with other complications—e. g., bacterial rot and the brown specking mentioned above—in regard to which it was not determined with certainty whether or not the fungus was present. Under "Diseased with *Fusarium*" are all those known to be attacked by the fungus, i. e., those presenting typical symptoms free from perplexing complications. The next six columns to the right—i. e., the eighth to the thirteenth, inclusive—represent the distance from the stem end to which the fungus had penetrated (see fig. 1). Taking as a basis a potato 12 centimeters long, if the fungus has penetrated not more than 2½ centimeters the inroad is recorded as slight; from 2½ cm. to 5 cm., "less than half;" from 5 cm. to 7 cm., "half;" from 7 cm. to 9 cm., "more than half;" from 9 cm. to 11 cm., "nearly all;" from 11 cm. to 12 cm., "all;" these distances measured on the long axis of the tuber. The last column shows the number in which tufts of white mycelium are present, as in Table III, but in different order. In this table the arrangement is such that the effects of like amounts of the same fertilizer can readily be compared in the three varieties of potatoes studied to see if there is any difference in varieties in regard to resistance to the disease.

A careful study of these tables shows that no one fertilizer stands preeminently at the head of the list in any table for all three varieties. If any one fertilizer either furthered or retarded the action of the fungus, we should expect to find it relatively near the head or foot of the list for all varieties and for both amounts used, but such is not the case. That is, for example, in Table I the plot of Burbanks fertilized with 8 grams of boneblack has the highest percentage of diseased tubers, while the checks are much farther down and widely separated; but, in the case of the Early Rose, boneblack, 8 grams, comes below three of the checks. Furthermore, in the Burbank plots the lesser amount of boneblack comes before the greater in the list, while, with the Early Rose, the reverse is true. A similar comparison of any other two fertilizers used shows similar inconsistencies. One would expect the checks of each variety to be together in the table, but though such is the case with the Early Rose in this table those of the Burbanks are widely separated, more than half the list lying between them.

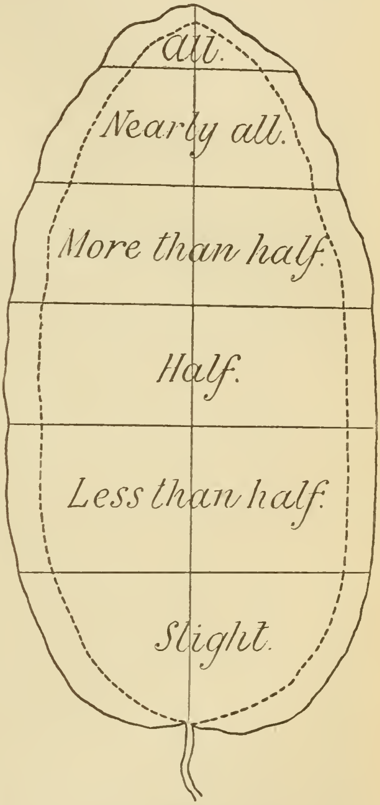

FIG. 1.—Diagram of a longitudinal section of a diseased tuber.

In Table II the comparison is no better. Here Burbank, potassium sulphate, 8 grams, stands first, with one check close below and the other almost at the end of the list, while, with the Early Rose, potassium sulphate, 8 grams, stands below the middle with one check eight numbers above and the other five below. It will be seen that in both varieties the two checks are widely separated.

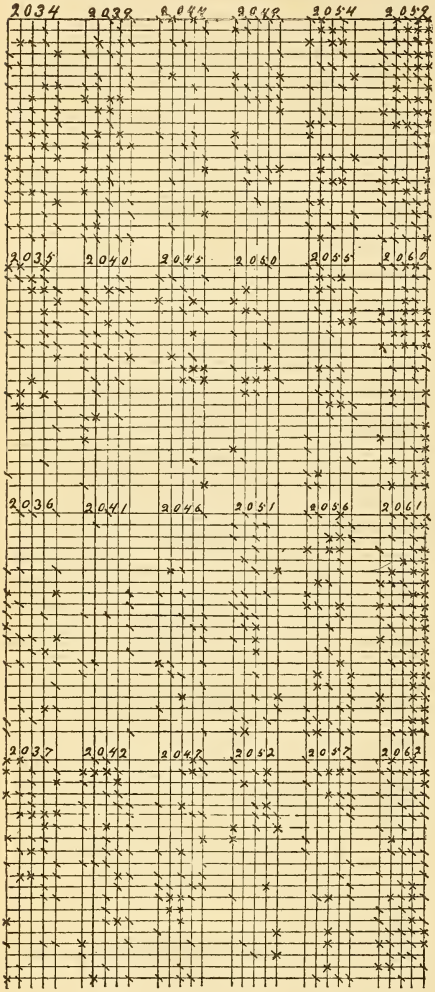

Fig. 2.—Diagram of experimental potato field, showing the cases of the *Fusarium* disease of potatoes found in the plots on July 27, 1902. A cross indicates that all the shoots in that hill were affected. An oblique line indicates that a part only of the shoots were affected. Small plots are omitted.

In Table III, Burbank, potassium sulphate, 16 grams, stands first, with one check a third of the way down the list and the other nearly at the end, and, with the Early Rose, potassium sulphate, 16 grams, is third from the end with one check three and the other nine numbers above.

Comparing the varieties in Table IV, we find equal complications. With boneblack, 16 grams, in the column showing the percentage diseased, Burbank has the highest per cent, Early Rose next, and "Brown" third, but with lime, 75 grams, Early Rose stands highest, Burbank second, and "Brown" third, while with potassium sulphate, 16 grams, Burbank is highest, "Brown" second, and Early Rose third. Comparing them in the last column, which represents the percentage showing white tufts of mycelium, we find that with boneblack, 16 grams, Burbank is highest, Early Rose second, and "Brown" third; with lime, 75 grams, "Brown" is highest, Early Rose next, and Burbank third; and with potassium sulphate, 16 grams, Burbank is highest, "Brown" second, and Early Rose third. Many other such comparisons can be made through the table, but no one variety can be found constantly with a higher or a lower percentage in any one column.

From a study of these tables one conclusion is very apparent, viz, that other factors than the fertilizers and varieties have taken a part in determining the relative extent and severity of the disease in the different plots. What these factors are has not as yet been determined. In the treatment of the ground while the potatoes were growing and during the previous year, and in the seed tubers planted, there was no appreciable difference. Neither would the location in the field of the different plots be expected to make any considerable difference (fig. 2). There was a plantation road on two sides, other potatoes from the same lot of Burbank seed on a third side, and bluegrass on the fourth, and none of these would be expected to have any effect on the prevalence of the disease in the experimental plots, especially as the roads were very wide, so that passers-by rarely came in contact with the plants. In the storage of the tubers during the winter there was the chief difference in treatment; but even here, as will be seen from the previous description of how the potatoes were kept, the only essential difference was in the pressure the various bags had to sustain and the fact that the upper tier was bounded above by a layer of cotton and the lower one lay in contact with a cement floor. These conditions can scarcely be considered sufficient to account for the differences found in the several plots.

During the early course of the disease the distribution in the field was very uneven. Exact data as to what plants were affected at any one time could not be obtained, as during the early stages of infection there was no change in the appearance of the tops, and a minute examination of the roots and tubers could not be made without destroying the future usefulness of the plots. A careful examination of the leaves and shoots was made, however, on July 27, and a record was taken of all those hills in which the disease had progressed far enough to show symptoms above ground. The distribution of these is shown in fig. 2. This represents a diagram of the field, showing the arrangement of the plots, fertilizers used, and the distribution of the plants showing the disease in the tops on July 27. The lines represent the potato rows, and their intersections represent the hills. The hills entirely diseased are marked with a cross; those partially diseased, with an oblique line.

Table V.—*Distribution of disease in the field, July 27, 1902, as determined by inspection of parts above ground.*

Plot.	Variety.	Fertilizer.		All diseased.	Part diseased.	Total.
		Kind.	Amount.			
			Grams.			
2059	Early Rose	Check		29	40	69
2061	do	do		27	34	61
2062	Burbank	do		14	39	53
2060	do	do		27	24	51
2034	Early Rose	Lime	75	11	38	49
2039	do	Sulphate of potash	8	13	31	44
2037	Burbank	Lime	25	16	24	40
2056	Early Rose	Nitrate of soda	16	15	25	40
2042	Burbank	Boneblack	8	9	29	38
2054	Early Rose	Muriate of potash	16	16	20	36
2047	Burbank	Boneblack	16	10	23	33
2055	do	Muriate of potash	16	10	23	33
2051	Early Rose	Nitrate of soda	8	6	26	32
2049	do	Muriate of potash	8	6	24	30
2035	Burbank	Lime	75	13	16	29
2036	Early Rose	do	25	6	23	29
2040	Burbank	Sulphate of potash	8	5	24	29
2057	do	Nitrate of soda	16	7	21	28
2045	do	Sulphate of potash	16	9	11	20
2044	Early Rose	do	16	5	16	21
2052	Burbank	Nitrate of soda	8	9	12	21
2046	Early Rose	Boneblack	16	3	16	19
2050	Burbank	Muriate of potash	8	8	9	17
2041	Early Rose	Boneblack	8	0	12	12

Table V gives the percentage in each plot that showed the effect of the disease in the tops on July 27. A study of this table reveals the fact that the distribution of the disease does not consistently follow either variety or fertilizer, neither are the plots in the same relative position in this table and in Table I. It also shows that at this date the checks were more seriously affected than any of the fertilized plots.

The distribution of the disease in the "Browns" does not appear in figure 2 or in Table V, as the leaves of these plants were so badly affected with "tip-burn" at the time the notes were taken that it could not always be told which were affected with the *Fusarium* disease.

From what precedes, it appears that though fertilizers and varieties may have some influence on the resistance of potatoes to the *Fusarium* disease, in the case of those particular fertilizers and varieties tested this effect was so slight that it was entirely hidden by the effect of other factors as yet little understood.

The experiments were repeated in 1903 on the same land, using the same fertilizers and same varieties, but with healthy seed potatoes obtained from a distance. The results were abundant scattered development of the disease on the foliage and tubers in summer and fall and slow increase of the disease in the stored tubers during late autumn and early winter. The tubers were stored in a cool, dry place, and when examined late in December a very large majority of them were found affected with the brown or black stain in the vessels at the stem end, but this rarely extended in more than 1 cm. and the tubers appeared sound externally. Bacterial decay was rare. In the sacks of tubers examined December 21 less than 10 per cent were free from the *Fusarium* disease. The slower progress of the disease in the stored tubers in 1903 was undoubtedly due to the fact that they were housed in a much cooler place. Cultures were made from the blackened vascular system in 24 of these potatoes. All yielded the fungus. Some also yielded bacterial colonies of various sorts. As in the cultures made from the crop of the preceding year the fungus did not, like the bacterial colonies, spring up at random anywhere on the surface of the potato block, but grew out of the deeper portions of the vascular system, first, as separated sparse hyphæ, then as luxuriant masses of sporiferous mycelium.

DESCRIPTION OF THE FUNGUS.

The form, color, and habits of growth of this fungus depend much on the medium in which it is grown. As it is found in the diseased plants, the mycelium is rather slender, with frequent septa, nearly colorless, and much branched in the parenchyma, but less so where it follows the xylem ducts (Pl. VIII, fig. 34). There are a few microconidia borne inside the host, but they are not numerous except where there is a cavity of some kind, and are, therefore, easily overlooked. Where the fungus breaks out in tufts on the surface of the tubers it is white or pinkish, and bears an abundance of microconidia, often many macroconidia, and sometimes chlamydospores. These tufts are from a few millimeters to several centimeters in diameter, and usually a little less than a centimeter tall. The individual hyphæ in these tufts are very much branched, with many septa.

In the many different kinds of culture media used this fungus showed a number of very striking variations. For this reason it is impossible to give a general description that will hold universally.

Sugar-beet agar (789[a]) was most used for poured plates, and boiled potato cylinders (792 and others) were the standard medium for tube cultures, as they afforded the same food as the host, differing only in being boiled.

The fungus used for all the comparisons on different media has descended directly from a single spore that developed in a plate poured from the interior of a tuber that was affected with the *Fusarium* disease only. The outside was pared off and the exposed surface sterilized with a hot spatula. A slice was then cut off with a hot scalpel and a little of the diseased part underneath was transferred with a sterile instrument to beef bouillon. This was used to inoculate tubes of beef agar from which six plates were poured. Only fungus colonies appeared in these plates, and these seemed to be all alike. A little of one of these colonies was transferred to a tube of boiled potato, and this was used as a starting point for the inoculation of the different culture media. The fungus was obtained in pure cultures from many other tubers and compared with the one just described to make sure that it was the true parasite under investigation. Three kinds of spores are produced by this fungus—microconidia, macroconidia, and chlamydospores. These will be described in detail a little farther on.

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[a] These numbers are given to the culture media when they are made up, and appear as a permanent record in the laboratory, with an exact description of the entire process by which they are made. These descriptions may be found near the end of this bulletin (pp. 55–59).

MYCELIUM.

On poured plates of sugar-beet agar (789), the spores germinate in a few hours at moderate temperatures (20° to 27° C.) and in about twenty-four hours the colonies become visible to the naked eye. They grow in diameter rapidly, being at the end of nine days about 6 to 7 centimeters across, if the growth is not interfered with by the sides of the dish or by other colonies. The margin is as a rule approximately circular, though not exactly so. Such a colony 9 days old is shown in Plate VII. These colonies are made up of concentric zones. In the center is a rather dense tuft about 3 millimeters high. Outside this is a zone in which the aerial mycelium is very short; farther out is a second zone of mycelium, about as dense as that in the center and somewhat taller—5 to 10 millimeters high. The rest of the colony making up the outside zone is of short mycelium, and this shows several concentric rings, caused by different degrees of density in the mycelium and abundance of spores. As the colony grows older the zone of taller mycelium becomes wider, but this widening is much slower for a time than the growth of the outer zone. Eventually, however, the entire colony produces the taller mycelium. Microconidia are borne in all parts of the colony, except the extreme margin of about 1 millimeter. They are not confined to the part above the surface of the substratum, but are also formed in the agar itself. In the extreme edge of the colony the hyphæ are seen to be pushing out radially with very little branching, while a little farther back lateral branches are being pushed out (Pl. VIII, fig. 1). Still farther back the microconidia and macroconidia are being formed, and a little later the chlamydospores. While very young the mycelium is usually densely crowded with granular protoplasm, but later it becomes much vacuolated. The cells, at least many of them, are uninucleated.

MICROCONIDIA.

The mode of formation of the microconidia was best studied in plates of sugar-beet agar. For this purpose specially made petri dishes with extra thin bottoms were used. By inverting these on the stage of the microscope the growth of the fungus could be studied without injury or disturbance to the cultures.

The method by which the microconidia are produced is shown in Plate VIII, figures 2–12. The end of a long hypha, or more usually a lateral branch, is directly cut off from the remaining portion by a very wide constriction furrow (Pl. VIII, fig. 3). The time taken to do this is difficult to ascertain with exactness, as the furrow is at first so very wide that it can not be distinguished from the many slightly narrower places in the mycelium found at irregular intervals. It is certain, however, that it does not require more than half an hour as a rule, and often not more than half that time.

As soon as one of these microconidia is cut off the hypha begins to elongate, pushing past it, if it is embedded in the agar, so that it can not fall off, or shoving it out of the way. This continues until the point has advanced even with the farther end of the first microconidium, but even before this growth is complete a similar constriction furrow begins to cut off a second microconidium (Pl. VIII, fig. 6). This process continues until sometimes as many as six or eight microconidia are formed from one branch, and lie side by side in a little group. The time from the cutting off of one until the cutting off of the next has been observed to vary from 2 to 5 hours. The microconidia are oval or elliptical in shape, thin-walled, one-celled, uninucleate, and slightly curved. They vary in length from 5.4μ to 16μ, and in diameter from 2μ to 2.7μ, the most common size, when growing in this medium, being 9.8μ in length by 3.2μ in diameter.

The time required for germination varies somewhat in different media, and greatly for the different individuals in the same medium. To determine this a tube of each of several kinds of media was inoculated copiously from a culture 36 days old growing on boiled potato made +25 on Fuller's scale with tartaric acid, and which contained all three kinds of spores in abundance. From each of these tubes two Van Tieghem cells were made, and examined at frequent intervals for several hours. The temperature of the room was from 22° to 26° C. The results are shown below.

In sterile distilled water a few microconidia began to germinate in 6 hours, and in 8 hours many were pushing out germ tubes. In 10 hours nearly half were germinating, but none of the germ tubes were very much branched. In 24 hours the process had advanced but little farther than in 10 hours.

In sugar-beet agar (789) germination began in 5½ hours, and in 9 hours about one-half the microconidia were germinating, though none were very far advanced; but in 13 hours practically all had germinated, and the young mycelium of many was somewhat branched. In 24 hours the mycelium had formed many microconidia, and a very few macroconidia and chlamydospores. After 4 days there were numerous microconidia and a few macroconidia and chlamydospores.

In beef bouillon (858) germination began in about 6 hours, and in

9 hours more than half the spores were germinating, though none had advanced very far. In 12 hours practically all had begun to germinate. In 24 hours a few microconidia and macroconidia had been formed, and a very few immature chlamydospores. After 4 days all three kinds of spores were numerous.

In Raulin's fluid (822) germination began in 6 hours, and in 9 hours about one-half of the spores had begun to germinate, though none had advanced very far. In 13½ hours practically all had begun to germinate. In 24 hours a few microconidia had been formed, but no macroconidia or chlamydospores could be found. After 4 days there were numerous microconidia and a very few macroconidia and chlamydospores.

In Uschinsky's fluid (841) germination began in about 6 hours, and in 9½ hours at least half the spores had sent out germ tubes, but these were not very complex. In 14 hours all the spores had begun to germinate. In 24 hours a few microconidia had been formed, but no chlamydospores or macroconidia were found. After 4 days the macroconidia were numerous, and there were a few microconidia and chlamydospores.

As all three kinds of spores were germinated in the same Van Tieghem cells, it was impossible to distinguish the mycelium of one from that of another after the time they began bearing spores.

In all the media except the distilled water the growth of the mycelium had progressed so far in 24 hours that it would have been almost impossible to trace all the branches belonging to some of the individuals, though others were still quite simple. Very few were left ungerminated in any of the media except distilled water, where more than half failed to germinate.

The germination of the microconidia is very simple (Pl. VIII, figs. 13–15). They first swell a little and become thick in proportion to their length—sometimes almost spherical; then at one end a germ tube is pushed out, and a little later another usually forms at the opposite end. Later these branch and become septate. The spore itself is noticeable for some time as a thickened place in the young mycelium and might easily be mistaken for a young chlamydospore.

MACROCONIDIA.

It is by this kind of spore that the form-genus *Fusarium* is commonly distinguished. In the one under consideration they vary much in size and shape, depending on the culture media used, though they are by no means of equal size in the same medium. In a Van Tieghem cell of Uschinsky's fluid (841), 5 days old, they vary from 10μ to 36μ in length and from 3.5μ to 6μ in diameter, 28μ by 4.5μ being the most usual size. In this medium they are from one to five septate, usually three, slightly constricted at the septa, not sharp-pointed, varying from nearly straight to very much curved (Pl. VIII, figs. 23–25).

In boiled potato (871), made +25 on Fuller's scale with tartaric acid, they are somewhat smaller and more sharply pointed. Those found in the cavities of diseased potatoes are usually very blunt at the ends. All are thin-walled and contain 1 nucleus to each cell.

The formation of the macroconidia is somewhat similar to that of the microconidia. They are not, however, borne beneath the surface of the substratum, and consequently drop off immediately. The process is therefore much more difficult to study. They are cut off from the ends of short lateral branches by constriction furrows (Pl. VIII, figs. 16–19). When first formed the macroconidia are somewhat smaller and less pointed than when mature, and usually have no septa, these being formed after 2 or 3 hours. Just how many may be constricted from the same branch was not determined definitely, because being borne only in the air they immediately dropped off and were lost, but as many as five have been counted, and probably there are often more. The branches that bear the macroconidia differ from those bearing the microconidia in having a swollen portion in the middle and a constricted portion at the base (Pl. VIII, figs. 16–19).

As with the microconidia, the time of germination varies much with the different culture media.

In sterile distilled water germination began in 3 hours. In 4 hours about half of the macroconidia had begun to germinate and in 7 hours practically all were germinating. The germ tubes never became much branched, however.

In sugar-beet agar (789) germination began in 5 hours; half the macroconidia were germinating in 5½ hours, and all had begun in 8 hours.

In beef bouillon (858) a few were germinating in 4½ hours, half in 6 hours, and all in 8½ hours.

In Raulin's fluid (822) a few were germinating in 5½ hours, half in 6 hours, and all in 8 hours.

In Uschinsky's fluid (841) a few had begun to germinate in 4 hours, half in 4¼ hours, and all in 7 hours.

In all these solutions practically every one of these spores germinated. In all but the distilled water the germ tubes grew and branched rapidly, so that at the end of 12 hours many of them were too complex to be traced. This was true of nearly all after 24 hours. The spores which formed in these cells in 24 hours and in 4 days have been mentioned under the germination of the microconidia which were in the same cells.

The germination of the macroconidia is somewhat complicated by the number of cells (Pl. VIII, figs. 20–22). The end cells usually germinate first, though this is by no means always the case, and the tube is sent out from the end of the cell, or, less frequently, from the side. Sometimes every cell in the spore germinates, but very often one or two near the middle of the spore fail to do so. As is the case with the microconidia there is a considerable swelling just before germination, and the spores are to be distinguished for a long time as swollen places in the mycelium.

The macroconidia produced in cultures vary in number according to the medium more than do the microconidia (Tables VII, IX, and X).

CHLAMYDOSPORES.

The chlamydospores are produced as swellings of the mycelium. These may be either intercalary or terminal, on long, comparatively straight hyphæ or short lateral branches (Pl. VIII, figs. 26–29). Sometimes there are several on the same hypha, close together like a string of beads.

The first indication of the formation of a chlamydospore is a slight enlargement at a certain point on a hypha, either at the tip or just behind a septum. This continues until a relatively large, nearly perfect sphere is formed, which is cut off by cross walls shortly before it reaches its definitive size (Pl. VIII, figs 26–29). The time required for a chlamydospore to mature is much longer than for a microconidium or a macroconidium.

The walls of these spores are relatively thick when mature, and seem to be made up of two layers, though this could not be brought out very sharply with Flemming's triple stain. They are smooth and light brown in color. The size in sugar-beet agar (789) varies from 5.5μ to 13μ, about 10μ being the usual size. All are one celled and each contains, at least at one stage, a single nucleus.

In boiled rice made so strongly acid that the growth was less than one millimeter high the chlamydospores were the only fruiting bodies found. Under such conditions they vary from their normal spherical shape and become very irregular, sometimes to such an extent as to be scarcely recognizable.

The chlamydospores are borne in abundance both in the substratum and above it, if the medium is favorable. They vary considerably in number according to the medium used, but, as will be seen from Tables VI–IX, at least a few were formed in every kind of medium in which the fungus was able to grow. They seem to be more resistant to unfavorable conditions than the other two kinds of spores but are hardly to be considered as resting spores, since in cultures a month old they germinate readily in a very short time; but here also this varies much with the medium used.

In the Van Tieghem cells described above, in distilled water the germination of the chlamydospores began in 4 hours, and at the end of 24 hours the germ tubes were only slightly branched. A little more than half entirely failed to germinate.

In sugar-beet agar (789) a few were beginning to germinate in 5 hours, half of them in 8 hours, and all in 10½ hours.

In beef bouillon (858) a few had begun to germinate in 4½ hours, half of them in 6 hours, and all in 8½ hours.

In Raulin's fluid (822) a few had begun to germinate in 6 hours, half of them in 8½ hours, and practically all in 12½ hours.

In Uschinsky's fluid (841) a few were beginning to germinate in 6 hours, about half in 9 hours, and practically all in 12 hours.

In all the media except the distilled water the germination of the chlamydospores was very complete, scarcely one failing to germinate. In nearly all cases 24 hours' growth had made the young mycelium much branched—often too much so to be followed.

As in the case of the microconidia, the germination is very simple (Pl. VIII, figs. 30–33). A germ tube is pushed out from one side, and this grows and branches into a complex mycelium. Cases have been observed in which there were two germ tubes, but these were rather unusual.

The chlamydospore is so much larger in diameter than the hypha that it remains very noticeable until hidden by the tangled mycelium.

Table VI shows more clearly a comparison of the germination of all three kinds of spores on the above media. All three were studied in the same Van Tieghem cells—two for each kind of medium. The inoculations were made at 10 a. m. from a 36-day culture. The temperature varied from 22° to 26° C. In a previous experiment, made at a temperature of about 30° C., the germination was somewhat more rapid.

TABLE VI.—*Germination of spores.*

Kind of medium.	Kind of spores.	A few spores germinating.	Half of spores germinating.	All of spores germinating.	Condition at the end of 24 hours.	Condition at the end of 4 days.
		Hours.	*Hours.*	*Hours.*		
Distilled water.	Microconidia	6	......	......	None of the germ tubes much branched. More than half of the microconidia and chlamydospores not germinated.	About the same as at the end of 24 hours.
	Macroconidia	3	4	7		
	Chlamydospores	4	......	......		
Sugar-beet agar.	Microconidia	5½	9	13	Many microconidia and a very few macroconidia and chlamydospores had been formed.	Very many microconidia and a few macroconidia and chlamydospores had been formed.
	Macroconidia	5	5½	8		
	Chlamydospores	5	8	10½		
Beef bouillon.	Microconidia	6	9	12	A few microconidia and macroconidia and a very few chlamydospores had been formed.	Many microconidia, macroconidia, and chlamydospores had been formed.
	Macroconidia	4½	6	8½		
	Chlamydospores	4½	6	8½		
Raulin's fluid.	Microconidia	6	9	13½	A few microconidia but no macroconidia or chlamydospores had been formed.	Very many microconidia and a very few macroconidia and chlamydospores had been formed.
	Macroconidia	5½	6	8		
	Chlamydospores	6	8½	12½		
Uschinsky's fluid.	Microconidia	6	9½	14	A few microconidia but no macroconidia or chlamydospores had been formed.	Very many macroconidia and a few microconidia and chlamydospores had been formed.
	Macroconidia	4	4½	7		
	Chlamydospores	6	9	12		

The above table shows that for the germination of microconidia beef bouillon is rather the best medium used and distilled water decidedly the poorest.

For macroconidia distilled water is a little the best for the early stages of germination, though Uschinsky's fluid is nearly as good, and beef bouillon is rather the poorest, though there is but little difference between it and Raulin's fluid. In all of the media this spore form germinated a little earlier than the microconidia.

For chlamydospores beef bouillon is the best and distilled water the poorest.

Though not under the head of germination, this table also shows that, relatively speaking, sugar-beet agar produces the most microconidia, Uschinsky's fluid the most macroconidia, and beef bouillon the most chlamydospores. This is extremely interesting, as it shows very strikingly how much the medium influences the kinds of fruiting bodies produced.

Table VI also shows at how very early a period the spores are formed. From the fact that all three kinds of spores were germinated in the same cells, it would be impossible to say with certainty from which kind of spore the mycelium bearing microconidia, macroconidia, or chlamydospores came. There is much evidence, however, that the mycelium from any one kind will, under the right conditions, produce all three.

SCLEROTIA.

There are produced in all cultures on boiled potato small masses of green sclerotia not more than 5 mm. in diameter and irregular in shape. These are borne at the surface of the potato, often partly covered with white mycelium, and were not found on any of the other media used, not even on raw potato. These masses are light green in color—about the same shade as *Penicillium glaucum.* They are rather hard, and in sections stained with Flemming's triple stain appear only as tightly interwoven masses of mycelium and seem to have little to do with the formation of fruiting bodies. Their true significance and why they appear in this medium only have not been determined.

GROWTH IN DIFFERENT MEDIA.

A considerable number of different kinds of culture media was used. This was partly to learn the extent to which the fungus would modify itself under changed conditions of nutrition, but largely in the hope of discovering a successful method of inducing the formation of perithecia. It is a well-founded belief that many of the imperfect fungi could be made to bear perithecia if the right conditions were given them, and it is more than probable that in some cases at least the procuring of the proper kind of food may be the solution of the problem. In the case under consideration, however, the attempt was entirely unsuccessful, not a single perithecium being found in any of the cultures. Whether this was because the right medium was not found or because in this case the necessary condition was some other than that of food supply, or whether the perithecial stage has been entirely lost from the life history of the fungus through many generations of asexual reproduction, can not be said with certainty at this time.

Many very interesting differences in the growth were, however, found in the various kinds of media used. At least four tubes of each kind of medium were inoculated, of which two were kept in a dark closet and two were suspended in a rack close to a north window, where they were exposed to strong daylight but not to direct sunshine. Careful notes were made on all these cultures at frequent intervals for several weeks. In all cases the growth was apparent to the naked eye in 24 to 36 hours. The growth in darkness was in no case materially different from that in light *except as to color*. (See p. 48.)

Pieces of sacks.—Many fragments of old sacks in which the potatoes had been stored were rolled into cylinders, thrust into test tubes, wet with distilled water or peptone water, sterilized, and inoculated. Growth was not very abundant and no perithecia developed.

Potato agar (*773*).—Growth about 4 mm. high, and rather sparse. In darkness, pure white; in light, very faint salmon—nearly white. Agar not changed in color; surface smooth.

Potato agar, peptonized (*774*).—Growth a very little more abundant than in 773; in light the salmon tint is very slightly more pronounced. Not different otherwise.

Beef agar (*786*).—Growth rather poor, not more than 2 or 3 mm. high and only moderately dense. Pure white both in darkness and in light. The agar is somewhat browned by the fungus, and the surface is wrinkled and uneven.

Sugar-beet agar (*789*).—Growth about 5 mm. high and very dense. Pure white in darkness, changing to creamy white with age; pale salmon in light. Agar not discolored but much wrinkled on the surface.

Beef gelatin (*793*).—Growth about 6 mm. high and very dense. White in darkness, changing to creamy; in light, rich salmon. Does not liquefy the gelatin.

Litmus lactose agar (*821*).—Growth about 2 to 3 mm. high, moderately dense. Grayish white in darkness; pale salmon in light. The fungus slowly turns the litmus blue, especially at the top of the slant, showing it to be an alkali producer in this medium. The change in color begins to be noticeable in about 10 days and goes on as long as the fungus remains active. It also reduces the litmus somewhat. Surface of medium much wrinkled.

Boiled potato (*792*).—Growth about 4 mm. high and very dense. In darkness, pure white, changing to creamy white; in light, rich salmon color. Contrast very striking. There are irregular masses of green sclerotia formed on the surface of the potato. The potato itself is gradually turned light brown. In old cultures it is much softened also.

Raw potato.—Growth about 4 mm. high and very dense. In darkness, pure white; in light, very pale salmon color. None of the green sclerotia are produced on the surface. The fungus acts on the starch grains without forming notches or marks of corrosion.

Boiled rice (*796*).—Growth about 4 mm. high, moderately dense. In darkness the mycelium is mixed pink and lilac, shading into white—the latter color being mostly at the extreme top of the mycelium, but it is to be found in places all through the culture; in light, a deep rich salmon color, shading into salmon pink mixed with lilac.

Boiled beans (*829*).—Growth about 4 mm. high and rather dense. In darkness, pure white, changing to gray and finally to grayish brown; in light, the same.

Boiled corn (*828*).—Growth about 4 mm. high and very dense. In darkness, creamy white with a few streaks of purple and sometimes a little pink; in light, the same but with a little more purple.

Boiled wheat (*827*).—Growth about 4 mm. high and very dense. In darkness, creamy white streaked with lilac and pink; in light, the same.

Boiled tapioca (*826*).—Growth extremely short, scarcely rising above the surface of the medium, but very dense. The fungus spreads very slowly and does not entirely cover the surface of the slant for nearly two weeks. In darkness, mycelium at first pink, then lilac, with white in the upper part of the slant; the lilac finally turns to dark violet. In light, the same, except that in the upper part of the slant the mycelium is very pale salmon.

Boiled sweet potato (*823*).—Growth poor, about 3 or 4 mm. high but rather sparse. The mycelium shows a strong tendency to grow into little bundles or ropes. In darkness, pure white, changing to yellowish white; in light, rich salmon.

Boiled banana (*824*).—Growth about 4 mm. high, moderately dense, and, like that in 823, inclined to collect in little ropy bundles. In darkness, pure white, changing to creamy white; in light, rich salmon.

Boiled prunes (*830*).—Growth poor, about 3 mm. high, and rather sparse. Slightly ropy. In darkness, white at first, changing to a light cinnamon-brown; in the light, the same.

Silicate jelly (*833*).—Growth about 3 mm. high and rather dense. In darkness, at first pink, which becomes a rose color with a trace of lilac, but the new mycelium is white; in light, the same, except that the new mycelium is a rich salmon. In both light and darkness the jelly is turned to a pale yellowish color.

In all the agars, in the gelatin, and in the silicate jelly the mycelium seems unable to penetrate the substratum more than 2 or 3 mm. In the other media the fungus seemed to vary considerably. In the boiled potato the mycelium sometimes grew from the inoculated slant directly through the cylinder to the opposite side. In the corn, wheat, beans, and rice the mycelium filled the chinks between the grains, but did not show in the lower part of the tubes, where the medium formed a solid mass. When there was some liquid in the bottom of the tube, as in the potato, banana, and sugar-beet cylinders, for example, the fungus kept above the surface of this liquid.

Microconidia, macroconidia, and chlamydospores were found in cultures on all these media, but their relative abundance varied greatly. In most of the media all were present in considerable numbers, but in boiled tapioca and beans only occasional chlamydospores were found, and in boiled prunes only occasional macroconidia. Here also microconidia were fewest.

A comparison of the cultures in these various media is shown in Table VII.

TABLE VII.—*Comparison of growth of Fusarium in different media.*

Kind of medium.	No. of medium.	Height of growth.	Density of growth.	Kinds of spores.			Color in darkness.	Color in light.	Remarks.
		Mm.							
Potato agar	773	4	Sparse	Macroconidia	Microconidia.	Chlamydospores.	Pure white	Very faint salmon	Surface of agar smooth.
Potato agar	774	4	do	do	do	do	do	Pale salmon	Do.
Beef agar	786	2–3	Moderately dense.	do	do	do	do	Pure white	Surface of agar wrinkled.
Sugar-beet agar	789	5	Very dense	do	do	do	Creamy white	Pale salmon	Do.
Beef gelatine	793	6	do	do	do	do	do	Rich salmon	Not liquefied.
Litmus lactose agar	821	2–3	Moderately dense.	Few macroconidia.	do	Few chlamydospores.	Grayish white	Pale salmon	Alkali producer reduces litmus.
Boiled potato	792	4	Very dense	Macroconidia	do	Chlamydospores.	Creamy white	Rich salmon	Forms green sclerotia.
Raw potato		4	do	do	do	do	Pure white	Pale salmon	No sclerotia.
Boiled rice	796	4	Moderately dense.	do	do	do	Lilac, pink, and white	Lilac, salmon-pink, and rich salmon,	
Boiled beans	829	4	do	Few macroconidia.	do	Occasional chlamydospores.	Gray	Gray	
Boiled corn	828	4	Very dense	Macroconidia	do	Chlamydospores.	Purple, pink, and white.	Purple, pink, and white	
Boiled wheat	827	4	do	do	do	do	do	do	
Boiled tapioca	826	1	do	Few macroconidia.	do	Occasional chlamydospores.	Deep violet and white	Deep violet and pale salmon.	Growth spreads very slowly.
Boiled sweet potato	823	3–4	Rather sparse.	Macroconidia	do	Few chlamydospores.	Yellowish white	Rich salmon	Mycelium forms ropy strands.
Boiled banana	824	4	Moderately dense.	do	do	Chlamydospores.	Creamy white	do	Do.
Boiled prunes	830	3	Rather sparse.	Occasional macroconidia.	Few microconidia.	Few chlamydospores.	Light cinnamon brown.	Light cinnamon brown.	
Silicate jelly	833	3	Moderately dense.	Macroconidia	do	Chlamydospores.	Pink, rose, lilac, and white.	Pink, rose, lilac, and salmon.	Changes medium to pale yellow.

In tubes of liquid media the growth varied greatly.

In beef bouillon (898) the fungus formed after 5 days a rather dense white layer on the surface, with much mycelium down in the liquid. All three kinds of spores numerous.

In Raulin's fluid (822) the growth in 5 days was about the same as above, except that all above the surface was a rosy pink. Spores rather less numerous, especially macroconidia and chlamydospores.

In Uschinsky's fluid (841) the growth on the surface was a little less than in the preceding, and pure white. Macroconidia especially abundant, but microconidia and chlamydospores present also.

In a solution (891) containing 2 per cent of Witte's peptone, 1 per cent dextrose, 1 per cent maltose, and 1 per cent mannite, the growth on the surface of the liquid after 5 days was rather abundant and pure white. All three kinds of spores present.

In water with Witte's peptone 2 per cent, glycerin 1 per cent (892), the growth on the surface at the end of 5 days was rather poor and thin, pure white, and producing all three kinds of spores.

In all these liquid media the growth was densest on the surface, but there was a loose growth of mycelium running to the bottoms of the tubes. These same liquids were used also in fermentation tubes, to be described further on.

To determine whether or not any of the chemicals used as fertilizers in the field are markedly injurious or beneficial to the fungus it was grown on boiled potato, to which these substances had been added. Cylinders of potato weighing exactly 4 grams were put in tubes of such a size that when 1 cubic centimeter of liquid was added about one-fourth inch protruded above the surface. To three of these was added 1 c. c. each of 10 per cent KCl; to three, 1 c. c. each of 10 per cent K_2SO_4; to three, 1 c. c. each of 10 per cent $NaNO_3$, making the chemical added 2 per cent of the final product in each case. To each of three others was added 1 c. c. of a saturated solution of freshly prepared $Ca(OH)_2$, and to three others 1 c. c. each of distilled water. These tubes were all heated on three successive days at 100° for 10 minutes. They were then inoculated with the *Fusarium* and kept in a dark room.

On the second day after inoculation there was a little growth in all the tubes, but this was slightly more abundant in the checks, the others being about alike. On the third day the growth in the tubes containing KCl, K_2SO_4, and $Ca(OH)_2$ was almost as abundant as that in the check tubes, and in the tubes containing $NaNO_3$ it was slightly less. On the fourth day the growth was so abundant in all the tubes that practically no difference could be seen. It was pure white and covered the entire exposed surface of the potato.

From this experiment it is apparent that the fungus can accommodate itself perfectly to these chemicals in quantities vastly exceeding that which is ever stored up in a living potato tuber. It follows, then, as a natural conclusion that if these substances have any effect on the resistance of the plant to this disease it is by some modification in the host plant, and not because of the presence of the substances as such.

Boneblack was not used in this experiment because the principal ingredient that would affect the fungus is phosphoric acid, and that was tested along with other acids (Table IX) and found to be quite harmless to the fungus in not too large quantities; and the above conclusions would therefore apply to boneblack also.

GROWTH IN ALKALIS.

To determine the behavior of the fungus on alkaline media three alkalis were used—potassium carbonate, sodium carbonate, and sodium hydroxide. These were mixed in different proportions with rice and water. The results are shown in Table VIII.

TABLE VIII.—*Comparison of growth in media with varying kinds and amounts of alkali.*

Kind of medium.	Alkalinity of medium.[a]	No. of medium.	Height of growth.	Density of growth.	Kind of spores.			Color in darkness.	Color in light.
					Microconidia.	Macroconidia	Chlamydospores.		
			Mm.						
Rice with K_2CO_3	− 5	884A	2–3	Dense	Microconidia	Macroconidia	Chlamydospores	Dark lilac, pink, and white	Salmon and lilac.
Rice with K_2CO_3	−10	884B	2–3	do	do	do	do	Pale lilac and white	Do.
Rice with K_2CO_3	−15	884C	2–3	do	do	do	do	do	Rich salmon and lilac.
Rice with K_2CO_3	−20	884D	1–2	do	do	do	do	do	Salmon.
Rice with K_2CO_3	−30	884E	2	do	do	do	do	Creamy white	Do.
Rice with K_2CO_3	−40	884F	2–3	do	do	do	do	do	Do.
Rice with K_2CO_3	−50	884G	1–2	do	do	do	do	Yellowish white	Do.
Rice with Na_2CO_3	− 5	885A	3–4	do	do	do	do	Lilac, pink, and white	Salmon and lilac.
Rice with Na_2CO_3	−10	885B	3–4	do	do	do	do	Pale lilac and white	Do.
Rice with Na_2CO_3	−15	885C	2–3	do	do	do	do	do	Do.
Rice with Na_2CO_3	−20	885D	2–3	do	do	do	do	White	Do.
Rice with Na_2CO_3	−30	885E	2–3	do	do	do	do	do	Rich salmon.
Rice with Na_2CO_3	−40	885F	1–2	do	do	do	do	Creamy white	Do.
Rice with Na_2CO_3	−50	885G	1–2	do	do	do	do	Yellowish white	Do.
Rice with NaOH	− 5	886A	2–3	do	do	do	do	Lilac and white	Salmon and lilac.
Rice with NaOH	−10	886B	2–3	do	do	do	do	Pale lilac and white	Do.
Rice with NaOH	−15	886C	2	do	do	do	do	White	Rich salmon and lilac.
Rice with NaOH	−20	886D	1	do	do	do	do	Creamy white	Do.
Rice with NaOH	−30	886E	1	do	do	do	do	Yellowish white	Rich salmon.
Rice with NaOH	−40	886F	1	do	do	do	do	do	Do.
Rice check (no alkali)		887	4	do	do	do	do	Lilac, pink, and white	Lilac, salmon pink, and salmon.

[a] Reckoned on Fuller's scale. For those not familiar with this scale it may be stated that the acidity or alkalinity is measured on one liter with normal solutions. Zero on the scale means neutral to phenolphthalein, + means acid and − means alkaline. The figures after the sign denote the number of cubic centimeters of normal acid or alkali required, as the case may be, to render one liter of the fluid neutral.

The difference in growth in the different strengths of alkali was most noticeable at the end of 2 days. At that time there was an even gradation in the amount of mycelium, lessening as the strength of the alkalis increased until at the maximum strength the growth was scarcely perceptible. This was true of all three alkalis. At that time the growth was rather best in potassium carbonate, a little less in sodium carbonate of the same strength, and still less in sodium hydroxide. It will be noted, however, that at the time Table VIII was made—i. e., when the cultures had been growing for 17 days—the amount of growth in the different tubes had been equalized considerably.

One of the most noticeable effects of the increasing strength of alkali was the decrease in the amount of pigment formed, especially the pink. At the end of 2 days there was in all the weak alkalis (−5) a very conspicuous purplish color, in those somewhat stronger (−10) this was a little less noticeable, but those of higher alkalinity were pure white. Later the purplish color changed to lilac, and in the carbonates (−5) there was a little pink.

All three kinds of spores were formed in all the alkali tubes, but in the higher strength the macrospores were very scarce.

GROWTH IN ACIDS.

To determine their effect on the growth of the fungus, a considerable number of acids were used, both inorganic and organic. Of the inorganic acids, phosphoric, hydrochloric, and nitric were tried. The organic acids used were selected partly with an idea of testing those most commonly found in the vegetable and animal products with which the fungus might come in contact in nature, but more especially with regard to their classification. Of the acetic series, formic, acetic, and butyric were taken—all monobasic; of the oxalic series, only oxalic, the simplest dibasic organic acid; of the hydroxy acids, malic and tartaric (dibasic), and citric (tribasic). As a preliminary experiment (series 1 in Table IX), these acids were mixed with boiled potato in such proportion as to make the product approximately +25. The experiment was carried on farther (series 2 in Table IX) by mixing the acids with rice and water in very definite proportions, so that the products would be of exact acidities. The results are shown in Table IX.

TABLE IX.—*Comparison of growth in acid media.*

SERIES I.

Kind of medium.	Acidity of medium.	Number of medium.	Height of growth.	Density of growth.	Kinds of spores.			Color in darkness.	Color in light.
			Mm.						
Potato—check (no acid added)		865	4	Very dense	Microconidia	Macroconidia	Chlamydospores	White	Rich salmon.
Potato with butyric acid	+25	866A		No growth					
Potato with formic acid	+25	866B	3	Very dense	Microconidia	Macroconidia	Chlamydospores	Pink and white	Do.
Potato with malic acid	+25	866C	4	do	do	do	do	do	Do.
Potato with lactic acid	+25	866D	3–4	do	do	do	do	do	Do.
Potato with citric acid	+25	866E	4	do	do	do	do	do	Pale salmon.
Potato with tartaric acid	+25	866F	4	do	do	do	do	do	Rich salmon.
Potato with acetic acid	+25	866G	3	do	do	do	do	do	Do.
Potato with oxalic acid	+25	866H	3–4	do	do	do	do	do	Lilac and pale salmon.
Potato with phosphoric acid	+25	866I	4	do	do	do	do	do	Pale salmon.
Potato with hydrochloric acid	+25	866J	3–4	do	do	do	do	do	Rich salmon.
Potato with nitric acid	+25	866K	3–4	do	do	do	do	do	Faint salmon.
Potato with sulphuric acid	+25	866L	3–4	do	do	do	do	do	Pale salmon.

SERIES II.

Kind of medium.	Acidity of medium.	Number of medium.	Height of growth.	Density of growth.	Kinds of spores.			Color in darkness.	Color in light.
			Mm.						
Rice with butyric acid	+ 6¼	872*a*	4						
Rice with butyric acid	+ 12½	872*b*		No growth					
Rice with butyric acid	+ 25	872A		do					
Rice with butyric acid	+ 50	872B		do					
Rice with butyric acid	+100	872C		do					
Rice with butyric acid	+150	872D		do					
Rice with formic acid	+ 6¼	873*a*	3	Dense	Microconidia	Macroconidia	Chlamydospores	Lilac, pink, and white.	Lilac, pink, and rich salmon.
Rice with formic acid	+ 12½	873*b*	2–3	Rather dense.	do	do	do	do	Do.
Rice with formic acid	+ 25	873A		No growth					
Rice with formic acid	+ 50	873B		do					
Rice with formic acid	+100	873C		do					
Rice with formic acid	+150	873D		do					
Rice with malic acid	+ 25	874A	4	Very dense.	Microconidia	Macroconidia	Chlamydospores	Dark lilac, pink, and white.	Lilac and rich salmon.
Rice with malic acid	+ 50	874B	4	do	do	do	do	do	Do.
Rice with malic acid	+100	874C	3–4	do	do	do	do	Lilac, pink, and white.	Lilac and pale salmon.
Rice with malic acid	+150	874D	3	do	do	do	do	do	Do.
Rice with malic acid	+200	874E	2–3	Dense	do	do	do	do	Do.

TABLE IX.—*Comparison of growth in acid media*—Continued.

SERIES II—Continued.

Kind of medium.	Acidity of medium.	Number of medium.	Height of growth.	Density of growth.	Kinds of spores.			Color in darkness.	Color in light.
			Mm.						
Rice with malic acid	+300	874F	1–2	Dense	Microconidia	Few macroconidia.	Chlamydospores	Lilac, pink and white.	Lilac and pale salmon.
Rice with lactic acid	+ 25	875A	4	Very dense	do	Macroconidia	do	do	Lilac and rich salmon.
Rice with lactic acid	+ 50	875B	4	Dense	do	do	do	do	Do.
Rice with lactic acid	+100	875C	2	do	do	Occasional macroconidia.	Few chlamydospores.	do	Do.
Rice with lactic acid	+150	875D		No growth					
Rice with citric acid	+ 25	876A	3–4	Very dense	Microconidia	Macroconidia	Chlamydospores	Lilac, pink, and white.	Lilac and pale salmon.
Rice with citric acid	+ 50	876B	3–4	do	do	do	do	do	Do.
Rice with citric acid	+100	876C	2	Dense	do	do	do	do	Do.
Rice with citric acid	+150	876D	3–4	do	do	do	do	do	Pale salmon, salmon pink, and lilac.
Rice with citric acid	+200	876E	2–3	do	do	do	do	do	Do.
Rice with citric acid	+300	876F	2	do	do	do	do	do	Do.
Rice with tartaric acid	+ 25	877A	4	Very dense	do	do	do	Dark lilac, pink, and white.	Dark lilac and pale salmon.
Rice with tartaric acid	+ 50	877B	3–4	do	do	do	do	Lilac, pink, and white.	Lilac and salmon.
Rice with tartaric acid	+100	877C	3	do	do	do	do	do	Lilac and rich salmon.
Rice with tartaric acid	+150	877D	3	Dense	do	do	do	Pale lilac, light pink, and white.	Do.
Rice with tartaric acid	+200	877E	2	do	do	do	do	do	Do.
Rice with tartaric acid	+300	877F	1–2	do	do	Few macroconidia.	do	do	Salmon pink.
Rice with tartaric acid	+400	877G		No growth					
Rice with tartaric acid	+500	877H		do					
Rice with acetic acid	+ 6¼	878*a*	3	Dense	Microconidia	Macroconidia	Chlamydospores	Lilac, pink, and white.	Lilac and salmon.
Rice with acetic acid	+ 12½	878*b*	2	do	do	do	do	do	Do.
Rice with acetic acid	+ 25	878A		No growth					
Rice with acetic acid	+ 50	878B		do					
Rice with acetic acid	+100	878C		do					
Rice with acetic acid	+150	878D		do					
Rice with oxalic acid	+ 25	879A	3	Very dense	Microconidia	Macroconidia	Chlamydospores	Lilac, pink, and white.	Dark lilac and pale salmon.
Rice with oxalic acid	+ 50	879B	2–3	Dense	do	do	do	Pale lilac, light pink, and white.	Do.

Rice with oxalic acid	+100	879C	2	Dense	Microconidia	Few macroconidia.	Chlamydospores	Pale lilac, rose pink, and white.	Pale lilac and rich salmon.
Rice with oxalic acid	+150	879D		No growth					
Rice with phosphoric acid	+ 25	880A	4	Very dense	Microconidia	Macroconidia	Chlamydospores	Wine purple,[a] pink, and white,	Lilac, wine purple, and salmon.
Rice with phosphoric acid	+ 50	880B	2–3	do	do	do	do	do	Do.
Rice with phosphoric acid	+100	880C	1–2	Dense	do	do	do	Light wine purple, pink, and white.	Wine purple and rich salmon.
Rice with phosphoric acid	+150	880D	1	do			do	Rosy white	Melon color.[b]
Rice with hydrochloric acid	+ 25	881A	2–3	do	Microconidia	Macroconidia	do	Lilac, pink, and white.	Lilac and rich salmon.
Rice with hydrochloric acid	+ 50	881B	1	do			do	Pink	Rose pink.[a]
Rice with hydrochloric acid	+100	881C		No growth					
Rice with hydrochloric acid	+150	881D		do					
Rice with nitric acid	+ 25	882A	2	Dense	Microconidia	Macroconidia.	Chlamydospores	Pale lilac, pink, and white.	Pale salmon and lilac.
Rice with nitric acid	+ 50	882B	2	do	do	Few macroconidia.	do	do	Do.
Rice with nitric acid	+100	882C		No growth					
Rice with nitric acid	+150	882D		do					
Rice with sulphuric acid	+ 25	883A	4	Very dense	Microconidia	Macroconidia.	Chlamydospores	Lilac, pink, and white.	Do.
Rice with sulphuric acid	+ 50	883B	1	Dense			do	Rose pink ([a])	Rose pink.
Rice with sulphuric acid	+100	883C		No growth					
Rice with sulphuric acid	+150	883D		do					
Rice check (no acid)		887	4	Very dense	Microconidia	Macroconidia.	Chlamydospores	Lilac, pink, and white.	Lilac, salmon pink, and rich salmon.

[a] Ridgeway's.

[b] Standard Dictionary, page opposite 1722.

From the above table it will be seen that for the different acids, both organic and inorganic, there is a very remarkable difference in the degree of acidity that this fungus can endure. Butyric, formic, and acetic acids, the representatives of the acetic series, seemed to be decidedly the most injurious; malic, tartaric, and citric, the representatives of the hydroxy acid group, are much the least so. This difference is really very great, as is shown by the fact that the fungus will grow in citric acid, for example, at least 25 times as strong as butyric.

The general effect of all the acids is to increase the production of the pigments, both lilac and pink—particularly the latter. This is somewhat noticeable in the rice tubes (series 2), but much more so in the potato tubes (series 1), where if no acid be added the growth (in darkness) is almost always pure white.

All three kinds of spores are borne in varying proportions in all the acid cultures in which only one acid is used, except phosphoric +150, hydrochloric +50, and sulphuric +50. In these no macroconidia or microconidia could be found, but there was a large number of chlamydospores. These were not of the normal form shown in Plate VIII, figure 29, but were of varying sizes and shapes—often much deformed. This is a further indication that the purpose of these spores is to carry the fungus through adverse conditions.

Table X shows the results of mixing the acids in the culture media in various ways.

TABLE X.—*Comparison of growth in mixed-acid media.*

Kind of medium.	Number of medium.	Kind of acid.	Acidity.	Kind of acid.	Acidity.	Total acidity.	Height of growth.	Density of growth.	Kinds of spores.			Color in darkness.
							Mm.					
Rice with hydrochloric and sulphuric acids.	895A	Hydrochloric.	+25	Sulphuric.	+25	+50	1	Dense			Chlamydospores.	Pink.
Rice with hydrochloric and sulphuric acids.	895B	....do	+50	....do	+50	+100		No growth				
Rice with hydrochloric and nitric acids	895C	....do	+25	Nitric	+25	+50	2	Dense	Microconidia.	Macroconidia.	Chlamydospores.	Lilac, pink, and white.
Rice with hydrochloric and nitric acids	895D	....do	+50	....do	+50	+100		No growth				
Rice with sulphuric and nitric acids	895E	Sulphuric.	+25	....do	+25	+50		....do				
Rice with sulphuric and nitric acids	895F	....do	+50	....do	+50	+100		....do				
Rice with sulphuric and lactic acids	895G	....do	+25	Lactic	+50	+75	3	Dense	Microconidia.	Macroconidia.	Chlamydospores.	Lilac, pink, and white.
Rice with sulphuric and lactic acids	895H	....do	+50	....do	+50	+100		No growth				
Rice with sulphuric and lactic acids	895I	....do	+25	....do	+100	+125		....do				
Rice with sulphuric and lactic acids	895J	....do	+50	....do	+100	+150		....do				
Rice with tartaric and butyric acids	895K	Tartaric	+25	Butyric.	+6¼	+31¼		....do				
Rice with tartaric and butyric acids	895L	....do	+50	....do	+6¼	+56¼		....do				
Rice with tartaric and butyric acids	895M	....do	+25	....do	+12½	+37½		....do				
Rice with tartaric and hydrochloric acids.	895N	....do	+25	Hydrochloric.	+50	+75	1	Dense			Chlamydospores.	Pink.
Rice with tartaric and hydrochloric acids.	895O	....do	+50	....do	+50	+100	1	....do			....do	Do.

This table would indicate that in the case of two acids for which the maximum strength that will allow growth is the same, mixing in equal proportions forms a product that is injurious in the same degree as either one alone. It also goes to show that when the maximum acidity at which growth can take place in any one acid is reached, the adding of another acid in a quanity representing half its own maximum for growth, or, in the case of butyric acid, the adding of tartaric in comparatively small quantities stops growth entirely. The adding of a comparatively small amount of the slightly injurious tartaric to the maximum of hydrochloric (+50) did not prove much more strongly inhibitory than hydrochloric of the same strength alone.

GROWTH IN THE ABSENCE OF FREE OXYGEN.

So far as could be determined the fungus is a strict aerobe. To test this, inoculations were made in fermentation tubes filled with the following media: Beef bouillon (858); Uschinsky's fluid (891); Raulin's fluid (822); water with peptone 2 per cent + dextrose 1 per cent + maltose 1 per cent + mannite 1 per cent (891), and water with peptone 1 per cent + glycerin 1 per cent (892). Two fermentation tubes of each medium were inoculated. This was done by transferring a little mycelium bearing many spores past the curve at the bottom of the tube, from which point it rose in every case to the extreme top of the closed end. At the end of a week there was a fairly good growth in the open ends of all the tubes, corresponding very well to that in the same fluids in test tubes. This growth did not in any case, however, extend into the closed ends more than 2 cm. past the stem, which showed definitely that this fungus can not take its oxygen from the compounds contained in any of these liquids.

REACTION TO SUNLIGHT.

In many kinds of culture media the mycelium is white, in part at least, when grown in a dark closet. On some of these same media the mycelium becomes a beautiful rich salmon color when grown in sunlight. In just which media this reaction takes place, and to what extent, is shown in Tables VII to IX. It will be seen that the depth of the color varies much in different media. The most unexpected difference was found between boiled and raw potato. In the former the color is nearly as deep as in any medium used, while in the latter it is very pale even after a week's exposure to north light. The time at which the color appears varies, of course, with the strength of the light. On boiled potato in north light close to a window it begins to be noticeable in a young culture on the second day of exposure if the weather is clear, and reaches its maximum on about the fifth day, after which it slowly fades as the mycelium dies from old age. In direct sunlight one day's exposure is enough to bring the color in a sufficient amount to be visible. In cultures exposed to the light for a few days and then placed again in darkness the new growth is white, showing that the action ceases practically as soon as the light is withdrawn.

The rays of light that cause the salmon color to appear are all at the violet end of the spectrum. To test this, eight tubes of boiled potato were inoculated with the *Fusarium*, and two of these were suspended in a saturated solution of potassium dichromate, two in a 1 per cent solution of copper sulphate made strongly alkaline with ammonia and filtered to remove the copper oxide, two in distilled water, and two were kept in the dark. The solutions were in 16-ounce wide-mouthed cylindrical bottles, the tubes inserted through perforated stoppers. The tops were wrapped well with black paper and the bottles set where they would get the direct sunshine in the afternoon. In the water the color began to appear in less than forty-eight hours and continued to get deeper for several days. The tubes suspended in copper sulphate and potassium dichromate solutions were first examined on the fifth day, and in the former there was a fairly deep salmon color, while in the latter the mycelium was pure white and continued so as long as the experiment was carried on, which was nearly six weeks.

This light reaction may perhaps be valuable as distinguishing this *Fusarium* from others, as some have been tried in which the color did not appear. It is not strictly confined to this species, however, for it was found to be very marked in a *Fusarium* obtained from the interior of a cowpea vine, and which is probably the *Neocosmospora* described by Smith.[a]

RANGE OF TEMPERATURE FOR GROWTH.

The fungus grows very well on boiled potato at temperatures from about 15° to a little above 30° C. Below 15° the growth is slower and slower as the temperature is reduced, until at 5° C. the increase in the cultures from day to day is hardly perceptible. At 37½° C. no growth takes place in cultures that have been started at room temperature, and at the end of a few weeks' incubation at this temperature the cultures were entirely killed. This may perhaps be one reason why the fungus did not pervade the stems above ground. In the roots the temperature is kept somewhat reduced by the earth, but in the stems growing in the sun it presumably often rises above 37½° C. in Washington summer weather.

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[a] Bulletin No. 17, Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture.

NAME OF THE FUNGUS.

Many specific names have been given to *Fusaria* growing on the potato, and while some of these names may stand for distinct forms, this is not at all certain. Most of these names undoubtedly are synonyms, and for the purpose of this paper all are regarded as such. The earliest available name, therefore, has been used for the parasite under consideration, viz, *Fusarium oxysporum* Schlechtendal, 1824. The following are some of the names that have been applied to *Fusarium* growing on the potato, the specific differences, as will be observed, being only such as are now known to occur in pure cultures of the same fungus when grown under varying conditions, viz, slight differences in compactness of mycelial growth, variations in size and shape of spores, number of septa, odor, and color. The appended descriptions, when not otherwise stated, are translations from Saccardo's Sylloge Fungorum.

1824. *Fusarium oxysporum* Schlechtendal.

Sporodochium convex, subverrucose, rosy, finally breaking forth, rugulose and confluent; conidia small, curved, and very acute at both ends. On half-rotten tubers of potato. Schlechtendal himself says: "F. stroma convexum erumpens varium roseum superficie inaequali rugulosa, sporidiis parvis curvatis utrinque acutissimis."

1842. *Fusarium* (*Fusisporium*) *solani* (Martius) Saccardo.

(Sporodochium) globose, irregular, tomentose, whitish; hyphæ branching; conidia fusiform-falcate, 3–5 septate, 40–60 × 7–8μ, subhyaline.

Fusarium (*Fusisporium*) *solani-tuberosa* Martius. Berkeley says this is *Periola tomentosa* Fries.

Fusarium (*Fusisporium*) *solani-tuberosa* Desm. is transferred by Saccardo to *Pionnotes* as *P. solani-tuberosa.*

1846. *Fusarium didymum* Harting.

Same as *Fusarium solani*, according to De Bary.

1851. *Fusarium* (*Fusisporium*) *roseolum* (B. and Br.) Saccardo.

Sporodochium rosy red, delicate, floccose; hyphæ short, conidia curved, elongate, somewhat obtuse, 3–6 septate, subtorulose. Berkeley says of this: "Of a delicate rose red, forming thin floccose patches; fertile threads short; spores curved, elongated, slightly obtuse, 3–6 septate, often slightly projecting at each dissepiment."

1869. *Fusarium violaceum* Fuckel.

Sporodochium widely spreading, with a pleasant odor, violet cærulean; conidia fusiform, 2–3 septate, curved, 24–30 × 5–6μ. According to Saccardo, Fuckel's species is the same as *Selenosporium cæruleum* Lib. in Herb. c. icone, and he substitutes the name *F. cæruleum* (Lib.) Saccardo.

1878. *Fusarium diplosporum* C. and E.

Rosy, pulvinate; some conidia fusiform, acute at both ends, arcuate, nucleate, finally becoming 3-septate, 40μ long; others elliptical, uniseptate, 18 × 8μ.

1886. *Fusarium commutatum* Saccardo.

Sporodochium widely spreading, white, mealy-floccose; sporophores continuous, branching; branches ascending, subalternate; conidia at first globose, then fusoid, 3-septate, slightly curved. This is the fungus described and figured by Bonorden in 1851 as *F. candidum* Ehrenb., but Saccardo says hardly *F. candidum* of Ehrenberg, and rejects the name apparently because of *F. candidum* Link.

1888 (?). *Fusarium pestis* Sorauer.

Sorauer may have described this fungus in some publication not seen by the writers, but there is no description of it in his Atlas other than what might apply to any of the foregoing. The brown spots on the stem are surrounded by a loose white narrow zone of hyphæ growing out of the stomata; later the black place is covered by a chalky white efflorescence (the fungous tufts).

1891. *Fusarium æruginosum* Delacroix.

Sporodochium large, hemispherical, varying from bluish to greenish ("e cyaneo æruginosis"), sporophores branching, sparingly septate, hyaline, with rather short branches; conidia falcate. 3–5 septate, not constricted, granular, hyaline or slightly greenish, 20–25 × 4–5μ.

1895. *Fusarium acuminatum* Ell. and Ev.

The authors describe this fungus as follows: "Sporodochia gregarious, minute, white at first, then flesh-colored; conidia falcate, attenuate-acuminate at each end, 3–5, exceptionally 6-septate, not constricted, arising from slightly elongated cells of the proligerous layer, in which respect it differs from the usual type of *Fusarium*. Quite distinct from *F. diplosporum* C. and E., which also occurs on the same host."

1896. *Fusarium affine* Fautr. and Lamb.

Sporodochia amorphous, dirty white, superficial or internal; conidia hyaline, cylindrical, attenuate, straight, at first simple then uniseptate, biguttulate, 10–15 × 4μ (inside of the stem). Authors describe external spores as 18–20 × 2μ.

If the potato disease here described is identical with the sleepy disease of tomatoes, as seems probable, then *Fusarium lycopersici* Sacc. may be added to the above.

Judged by the above descriptions, we have had a half dozen or more species of *Fusarium* in our culture tubes, some of them "new species," and yet all were the product of a single spore. This does not mean that there have been in our cultures any very wonderful transmutations of one thing into another, but only that organisms respond to their environment, and that "species descriptions" of the kind cited have not taken this fact into consideration, and consequently are worthless for scientific purposes. This is not a new idea, but it is a fact to which the attention of systematic mycologists might be directed profitably at frequent intervals.

GEOGRAPHICAL DISTRIBUTION OF THE DISEASE.

There is good reason for believing that this disease is very widely distributed over the United States. "Dry rot" has been known to be one of the most serious potato troubles for many years, and though it has not been so clearly described in most cases as to establish its identity with the disease under consideration, yet it is extremely probable that, in many cases at least, it is due to the same fungus.

It has been definitely identified from several different and widely separated States. As already stated, it was received in large quantities from Hubbardston, Mich., in 1899. In April, 1903, it was sent in from Alleghany Station, Va., where it had done very great damage to stored potatoes during the winter, so that the grower had been obliged to feed them to his hogs. About a half bushel of these potatoes was sent to the Department of Agriculture, and when cut open a large proportion showed the disease. Its identity was further established by microscopical examination and by making cultures of the fungus from the discolored part of the tubers. One diseased tuber was received from Manhattan, Kans., where there had been much loss in stored potatoes. This tuber was browned in the vascular ring throughout its entire extent. A few diseased vines and tubers were received in the summer of 1903 from Nebraska, where considerable injury was reported. Our own crop, raised on the Potomac Flats, established the presence of the disease in the District of Columbia. The disease reported by Stewart from several parts of New York State, and mentioned at the beginning of this paper, appears to be the same. It has also been sent to the Florida station of this Department from several of the Southern States. In the fall of 1903 it was observed in the vicinity of Madison, Wis.

It seems, then, safe to say that this disease extends north to Canada, east to the Atlantic, south to the Gulf of Mexico, and west to Colorado. How much wider its distribution is in this country can not be stated at the present time, but it is almost undoubtedly beyond the limits from which it has been so far reported.

If the disease in England, Germany, France, and Belgium be the same, it is certainly also widely prevalent in Europe.

REMEDIAL MEASURES.

As the fungus enters the plant below the surface of the ground and may gain access at any time during the season, it is very difficult to combat. Spraying with Bordeaux mixture and other fungicides has not been tried, but as these can be applied readily only to the tops there is little reason to expect beneficial results.

Adding chemicals to the soil as fertilizers might be expected to help ward off the disease, but so far as experiments of this kind have been carried out by the writers they have given practically negative results.

The selection of resistant plants of different varieties will be likely to prove of the most value. Our varieties all suffered severely with the disease, but some plants escaped, while others contracted the disease early in the growing season. In 1903, in our plots, above-ground symptoms were visible on a few plants as early as July 15, and many diseased plants were to be seen on July 22. A month later the disease was very conspicuous on the foliage in all parts of the field, but there were still many plants which showed no symptoms. Experiments with other varieties would be likely to establish the same partial immunity, and from the most resistant of these plants it is probable that hardy strains could be originated. According to Frank, the German disease also attacks some varieties more readily than others.

Planting on soil free from the disease, with sound tubers obtained from localities where the disease does not occur, is certainly to be recommended. The stem end of every tuber should be cut off and inspected before deciding to plant it. It is much easier to keep this fungus out of a soil than to overcome it when it is well established. It should be regarded in the same light as a very noxious weed, and every effort must be made to keep the potato fields free from it. A word to the wise is sufficient.

If tubers affected with this disease are used for seed, the resulting crop and successive crops will be attacked, as the fungus is thereby placed in the best possible position to infect the young roots, even if it does not grow into the new plants directly through the sprouts, which it is extremely likely to do.

It is of equal importance to avoid planting potatoes for several years on land where the disease has appeared, as the fungus keeps alive in the soil for some time—how long has not been determined.[a] Such infected land should be used for other crops, preferably cereals or grasses. Badly diseased tubers should not be fed to stock, as the heat of the animal body for so short a time is not sufficient to kill the spores, nor would the digestive fluids be likely to do so, and they would therefore be thrown out on the land ready to attack another crop. They should be burned or buried on waste land in a deep pit, with the addition of some barrels of caustic lime.

It has already been shown that when the potatoes are harvested the extent of the disease in those affected is usually comparatively slight—often quite unnoticeable to the casual observer.[b] It is while they are in storage that the greater amount of the destruction and consequent loss takes place. It becomes of very great importance, therefore, to know how to handle these slightly diseased potatoes so as to prevent the further progress of the fungus.

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[a] In the case of several diseases of this type it is known positively that land once infected remains infected for many years.

[b] If a potato disease that prevailed extensively in the fall of 1903 in several counties in Minnesota, which has been received more recently from Maryland and reported from Michigan, be the same, then this statement must be modified. This disease appears to follow wet weather, and is characterized by a hard, black stain running in from various parts of the surface of the tuber, often involving nearly the whole tuber, and seldom more than one centimeter deep. The infection in this disease is not by way of the vascular system, but seems to be from any part of the soil in contact with the tuber, and probably by way of the lenticels. The disease suggested *Phytophthora*, but the mycelium found in the tissues on microscopic examination did not belong to this fungus. Two sets of poured plates yielded *Fusarium* colonies, and the third set only some scattering bacteria. The losses in Minnesota amounted to thousands of dollars. Early digging would undoubtedly have prevented most of this loss.

First in importance is the question of temperature. Potatoes that show a slight trace of brown color in the flesh at the basal end should never be stored in warm rooms. They should be kept in a place as cool as it is possible to obtain without danger of freezing, i. e., at or below 40° F. This low temperature may be had in cool cellars, but is best obtained by our modern cold-storage processes, and here there is little danger of loss by continued growth of the fungus. For the average potato grower, however, cold storage is a process too expensive to be practicable. He must resort to storing in the ground or in cellars. Of these, pits in the ground or cellars under barns are likely to be cooler during the winter than cellars under houses, and on that account would be preferable for these slightly diseased potatoes, though there is, of course, a vast difference in the temperature of house cellars.

Where it is not practicable to store in a decidedly cool place, such potatoes should be sold in the fall. Except for the browned region at the base, the potatoes are not disqualified for eating, and this part, if not too extensive, can be removed in paring. This, however, involves a waste, and the quality of the unattacked parts of many of these tubers seems to be inferior. There is no danger in using these partially affected tubers. Cooking kills the fungus; but even if the tubers were eaten raw the fungus could do no harm to a human being, as it has been shown that it can not grow at blood temperature—37½° C.

Moisture is another factor to be considered, though to a much less extent than temperature. The fungus can grow readily and even rapidly in the tubers in a very dry air, but it has been shown that in a moist atmosphere there is a much greater production of mycelium on the surface, and consequently more spreading of the rot by contact. Furthermore, the tubers killed by the fungus, if kept dry, shrivel up and undergo no further change, but if there is moisture present they are invaded by various soft bacterial rots that may spread into the sound potatoes by contact, and thus increase the loss.

To recapitulate:

(1) Plant only sound tubers on uninfected land.

(2) Reject badly diseased tubers and store slightly diseased ones in a cool dry place, i. e., at 35° to 40° F.

(3) If rejection and storage can not be carried out as recommended above, sell soon after digging, or at least as early as December.

(4) When there is any suspicion, buyers should always keep the potatoes in cold storage.

(5) Stake the soundest, best-looking plants on diseased fields and save the tubers from such plants for further experiment in the hope of originating resistant strains.

CULTURE MEDIA USED.

That the reader may obtain a more accurate knowledge of the composition of each kind of medium used in the foregoing experiments and the details of the process by which it was made, to aid him in interpreting any peculiarities of the results the following descriptions are given. Unless otherwise stated in the text, the media were all used for tube cultures, and the tubes of the agar, the gelatin, the silicate jelly, and the boiled tapioca were all hardened at a long slant. When the nature of the medium was such that it could readily be measured, 10 cubic centimeters was the amount used for each tube. It is not to be understood that the following methods of procedure are recommended as always in all respects the best, but they are referred to only as those actually used.

Potato agar (773).—Very smooth, sound potatoes were thoroughly scrubbed, washed five times in distilled water, pared, washed again in distilled water, and sliced thin. To 200 grams of sliced potato were added 500 c. c. of distilled water, and the whole was heated in a steamer for 1½ hours at 75° to 85° C., then filtered hot, without pressure, through a clean towel. Water was then added to bring the amount up to 500 c. c. To half of this (250 c. c.) was added 7.5 grams of Lautenschläger's agar flour that had been heated with 250 c. c. of distilled water in an autoclave at 110° C. for 15 minutes. The potato infusion and the agar solution were then thoroughly mixed and heated in an autoclave at 110° C. for 10 minutes.

Peptonized potato agar (774).—Like 773 but with the addition of enough of Witte's peptonum siccum just before mixing with the agar solution to make the whole one-half per cent. The potato infusion used was half of the 500 c. c. prepared for 773.

Beef agar (786).—To one part finely chopped lean beef (918 grams) were added two parts (1,836 c. c.) distilled water. This was kept in a water bath between 50° and 60° C. for an hour, and then heated at 100° C. for an hour. It was then filtered hot in a meat press through a clean towel and cooled and filtered again through filter paper. Enough of Witte's peptonum siccum to make the final product 1 per cent was added and the whole heated to 100° C. for an hour and filtered through paper. Water was then added to bring the total amount back to 1,836 c. c. This bouillon was then titrated with phenolphthalein, and NaOH was added to make it +15 on Fuller's scale.[a] To 1,000 c. c. of this bouillon was added 10 grams of Lautenschläger's agar flour, and this was heated at 100° for half an hour and then cooled down below 60° C. The neutralized whites of two eggs were then added and thoroughly mixed to clarify the medium. It was then heated to 100° for one hour, filtered through paper, and autoclaved for fifteen minutes at 110° C.

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[a] See footnote on p. 41.

Sugar-beet agar (789).—A large sound sugar beet was thoroughly scrubbed, washed in distilled water, pared, and grated fine. To 1,000 grams of beet pulp was added 1,500 c. c. distilled water, and the whole was heated at 100° C. for half an hour, then filtered under pressure through a clean towel. Water was added to the liquid to bring the total amount up to 2 liters. This was titrated and found to be +3 on Fuller's scale. No alkali was added. Ten grams of agar flour were added, and it was then heated at 100° for three-quarters of an hour, filtered through filter paper, and heated again on three successive days for 10 minutes at 100° C.

Boiled sugar beet (790).—From the same beet used in making the above, cylinders about 1½ inches long were cut with a large cork borer. These were washed in distilled water and trimmed to a long slant at one end. They were then put in test tubes with a little distilled water and heated on three successive days for 10 minutes at 100° C.

Boiled potato (792).—Large sound potatoes were thoroughly scrubbed, washed in distilled water, pared, washed again, and cut into cylinders about 1½ inches long with a large cork borer. These cylinders were washed in distilled water, trimmed to a long slant at one end, washed again, and put in test tubes with a little distilled water. They were heated on three successive days in a steamer for 10 minutes at 100° C.

Beef gelatin (793).—To 500 c. c. beef bouillon (made precisely like that used for beef agar 786, including 1 per cent peptone) was added 50 grams of Nelson's No. 1 photographic gelatin. This was allowed to soak for 1½ hours, then heated in a steamer for 5 minutes at 100° C. It was titrated with phenolphthalein, and NaOH was added to make it +15 on Fuller's scale, then heated at 100° for 20 minutes and filtered. Heated in tubes on first day 10 minutes, and on second and third days 5 minutes each at 100° C.

Boiled rice (796).—Clean rice, 2½ grams, and distilled water, 10 c. c. per tube, were heated in the autoclave for 10 minutes at 115° C.

Litmus lactose agar (821).—To 500 c. c. of beef agar made like 786 was added 10 grams of lactose and just enough of Merck's purified litmus to make it a bluish color. Heated 10 minutes at 100°, pipetted into tubes, and heated on three successive days at 100° C. The tubes were laid so that the agar hardened at a long slant.

Raulin's fluid (822).—To 1,500 c. c. distilled water were added, in order: Cane sugar, granulated, 70 grams; tartaric acid, 4 grams; ammonium nitrate, 4 grams; ammonium phosphate, 0.60 gram; potassium carbonate, 0.60 gram; magnesium carbonate, 0.40 gram; ammonium sulphate, 0.25 gram; zinc sulphate, 0.07 gram; ferrous sulphate, 0.07 gram; and potassium silicate, 0.07. This mixture was heated on 3 successive days, for 15 minutes, at 100° C.

Boiled sweet potato (823).—Several small sweet potatoes were scrubbed, pared, washed in distilled water, cut into cylinders with a large cork borer, trimmed to a long slant at one end, and put in tubes with a little distilled water. Autoclaved for 10 minutes at 110° C.

Boiled banana (824).—Pieces of barely ripe yellow banana about ½ by 1½ inches were put in tubes with a little distilled water. Autoclaved for 10 minutes at 110° C.

Boiled rice (825).—Like 796.

Boiled tapioca (826).—Tubes were filled to the depth of 1 inch with pearl tapioca, and 10 c. c. of distilled water was added to each. After soaking for 4 hours they were autoclaved in a slanting position for 15 minutes at 115° C.

Boiled wheat (827).—Tubes were filled to the depth of ¾ inch with soft red wheat and 10 c. c. distilled water added. This was allowed to soak over night and then autoclaved three times for 15 minutes at 115° C.

Boiled corn (827).—Tubes were filled to the depth of ¾ inch with white dent corn, coarsely cracked, and 10 c. c. of distilled water added. After soaking for 3 hours they were autoclaved 3 times for 15 minutes at 117° C.

Boiled beans (829).—Tubes were filled to the depth of ¾ inch with coarsely cracked white navy beans and 10 c. c. distilled water added. After soaking 4 hours they were autoclaved for 15 minutes at 115° C.

Boiled prunes (830).—Several pieces of best quality prunes were put in tubes and 10 c. c. distilled water added. After soaking for 4 hours they were autoclaved for 10 minutes at 110° C.

Boiled sugar beet (831).—Made exactly like 790, except that the beets used were less than half grown.

Silicate jelly (833).—To 100 c. c. of hydrochloric acid, sp. gr. 1.10, was added drop by drop 100 c. c. sodium silicate, sp. gr. 1.107, the mixture being stirred constantly. This was dialyzed for 6 hours in running water. To 200 c. c. of this was added 50 c. c. of a solution like Raulin's, but more concentrated, the same weight of salts being used, but only 200 c. c. of water instead of 1,500 c. c. After thorough mixing, 10 c. c. quantities were pipetted into tubes and then were put in the autoclave in a somewhat inclined position and heated for 10 minutes at 110° C. The steam was not allowed to escape while the autoclave was cooling, and the jelly came out homogeneous and clear, and sufficiently hard.

Uschinsky's fluid (841).—To 500 c. c. of distilled water were added: Glycerin, 15 c. c.; ammonium lactate, 3 c. c.; sodium chloride, 1.5 grams; sodium asparaginate, 1.5 grams; dipotassium phosphate, 1 gram; calcium chloride, 0.05 gram; magnesium sulphate, 0.05 gram. This mixture was heated for 30 minutes at 100°, filtered, tubed, and autoclaved for 10 minutes at 110° C.

Beef bouillon (858).—This was made exactly like the bouillon for agar No. 786, except that 1,165 grams of beef and 2,330 c. c. of water were used, and the solution was heated only half an hour just afte the peptone was added. It was finally autoclaved 10 minutes at 115° C. The acidity was +15 and the peptone 1 per cent.

Boiled potato (865).—Made exactly like 792.

In sterilizing the following media the autoclave was heated to the boiling point, the tubes put in cold, and the cover screwed down immediately. As soon as steam began to come out freely, which was before the tubes were heated through, the vent was closed and no steam was allowed to escape until the sterilization was finished and the autoclave cooled down below the boiling point. This was to prevent any escape of the acids. All the tubes containing acids were autoclaved for 10 minutes at a temperature varying between 105° and 107° C.

The acids used were all titrated with great care and accuracy, N/20 sodium hydroxide and phenolphthalein being used. They were in all cases retitrated after diluting to the proper strength.

866A to L.—These were made by preparing potato cylinders like those in 865, and adding to each tube before sterilizing a little water and 1 c. c. of acid +250. As the size of the potato cylinder and the amount of water were made so that together they would weigh as nearly as possible 9 grams, the approximate acidity of the product in each case was +25. The acids used are shown in Table IX, series 1.

872 to 883.—Made by heating together rice water and acids in such proportions that the products would be of the exact acidities given in Table IX, series 2. The acids used for making the tubes of acidities up to and including +150 were all +250, those for +200 and +300 were +500, and the tartaric for +400 and +500 was +1,000. The amount of rice used for each tube was such that the cultures should be neither too wet nor too dry, and varied with the different acids.

884 to 886.—In preparing these alkaline media the sodium hydroxide used was from the N/20 used in titrating acid solutions, while the carbonate used were made −100 on Fuller's scale. In titrating them phenolphthalein was used as an indicator, and residual titration was resorted to (see Sutton's Volumetric Analysis, Sixth Edition, p. 50). In this sulphuric acid N/20 and sodium hydroxide N/20 were used. These alkalis were mixed with rice and water in proportions to give exactly the alkalinities stated in Table VIII.

895A to O.—The acids used in preparing these media were all +250. They were mixed with rice and water in proportions to give the acidities shown in Table X. All were autoclaved for 10 minutes at 110° C.

Raw potato cylinders (896).—Several large sound Burbank potatoes were thoroughly washed, soaked 5 minutes in 1:1,000 corrosive sublimate water, washed again in distilled water, pared with a sterilized knife. and washed again in distilled water. From these potatoes cylinders were cut with a sterilized cork borer and allowed to drop directly into tubes containing a little autoclaved distilled water. They were allowed to incubate for 2 weeks at 37½° C., and for 2 weeks longer at room temperatures; and at the end of that time all that showed any signs of bacterial or fungous growth were discarded. They were at this time nearly black on the surface from oxidation.

SUMMARY.

(1) This bulletin deals with a potato disease common over a considerable portion of the United States and variously known as bundle blackening, stem rot, dry end-rot, and dry rot.

(2) The bundle blackening and dry end-rot of the tuber are two stages of the same disease. This begins in the field in the underground stems and roots.

(3) A fungus is always present in the darkened vascular bundles of the tubers in sparing amount, and cultures therefrom have shown this to be a *Fusarium*.

(4) The above-ground symptoms are slow change of color, dwarfing, more or less rolling or curling of the leaves, and, finally, a wilt of the foliage and the falling down of the stems.

(5) The first symptoms in the tuber are nearly always at the stem end in the form of browned or blackened vascular bundles. During this stage of the disease the tubers are sound externally. The dark stain in the vessels may finally extend to the eye end of the tuber, the parenchyma within and without remaining sound and white or becoming yellowish as the fungus invades it (finally shriveled, grayish brown, and hard), or else breaking down with mixed infections including various soft bacterial rots.

(6) The fungus grows readily in a great variety of culture media. It varies considerably in form, color, and sporification according to the environment. On cooked potato and in a number of other media it is white when grown in darkness but bright salmon when exposed to the light. On cooked beans the fungus is gray both in light and in darkness. Under varying conditions various colors were obtained, e. g., purple, violet, lilac, pink, rose, yellow, cream, salmon, cinnamon, gray, and green. Macroconidia were more abundant in some media than in others, and in certain acid media only distorted chlamydospores were produced.

(7) The fungus tolerates large amounts of some kinds of acids, e. g., malic, citric, and tartaric, and is inhibited by small amounts of others, e. g., formic, acetic, and butyric. It endures considerable amounts of alkalis, and these have a tendency to keep the mycelium white, or when in excess to make it yellowish.

(8) The fungus is aerobic. It does not grow at 37½° C. (blood heat) and grows with extreme slowness at 5° C. (41° F.). It grows well between 15° and 30° C.

(9) The fungus attacks the plant from the soil and winters over in the earth. In land frequently planted to potatoes it can probably maintain itself indefinitely.

(10) A copious use of fertilizers, such as lime, phosphates, nitrates, and potash salts, did not enable the plants to overcome the disease.

(11) The disease continues in stored potatoes, and if they are kept in warm rooms the loss during the winter is likely to be large. Tubers stored by the writers in warm rooms, whether moist or dry, became badly diseased. Those stored in a cool place kept much better.

(12) Diseased tubers, therefore, should be stored in cool, dry rooms and used early in the season. They should not be fed raw to stock.

(13) Infected land should be planted to other crops for a series of years. Tentatively, at least, it would be best to exclude also tomatoes, eggplants, and peppers from such land.

(14) The greatest care should be taken to avoid the infection of healthy land by the planting of diseased tubers. All tubers designed for seed should be cut at the stem end and carefully inspected before planting.

(15) Diseased tubers should not be thrown on the manure pile.

(16) If the new wet-weather disease of potato tubers mentioned in the footnote on page 53 be due to this same fungus, then some modifications should be made in the statements in paragraph 5. It is probable, also, that in some climates or conditions the fungus will be found growing out into the parts above ground.

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[*Melanospora ornata* was frequently found inside the stems killed by this disease.]

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[This is the one described by Ellis and Everhart as *F. acuminatum.* Some potato stems sent to the station were observed to be girdled by a pink fungus. The disease is said to have spread rapidly for a few days in midsummer and then disappeared so that additional material for study could not be obtained.]

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[a] This list includes some of the more important references, but no attempt has been made to give a complete bibliography.

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[The date given on the cover is Dec., 1897, but the date of the letter transmitting the Bulletin to the State Commissioner of Agriculture for publication is Feb. 7, 1898. "The stem-blight herein discussed is the one described by the writer in Bul. No. 101 of this station, pp. 83–84."]

ROLFS, P. H. So. Car. Sta. Rpt., 1900, pp. 21–28.

[Note on a disease of potato thought to be caused by *Fusarium.*]

BERNARD. Compt. Rend. T. 132, pp. 355–357. Paris, 1901. See also T. 131, pp. 626–629, 1900.

[Potato tubers are supposed to be *galls* due to the stimulating influence of *F. solani.*]

DELACROIX, G. Jour. Agr. (Paris), 1901, Sept. 7, p. 7.

[Reports a form of *Fusarium* associated with a bacterial disease of potatoes supposed to be due to *Bacillus solanacearum.*]

DESCRIPTION OF PLATES.

PLATES.

Plate I. *Frontispiece.* Potato plant in which part of the shoots appears healthy, and part is affected with the *Fusarium* disease, showing difference in the habit of the affected part and particularly in the appearance of the leaves.

Plate II. Potato plant in a somewhat advanced stage of the disease, the foliage wilted and drooping, but the shoot not yet fallen over on the ground.

Plate III. Potato plant in a late stage of the disease, the shoots prostrate on the ground and the leaves drying up.

Plate IV. Sections cut across diseased tubers at the stem end, showing an earlier stage of invasion of the vascular system by the fungus than that shown in Plate V. Natural size.

Plate V. Figs. 1 and 2.—Sections cut across middle of diseased tubers, showing blackened condition of the vascular system. Fig. 3.—Tuber similar to Fig. 1, with the cortex carefully pared away so as to show the longitudinal extension of the brown stain in the vascular system. Fig. 4.—A later stage, showing extension of the disease to the whole interior of the tuber and tufts of white mycelium in the central cavities. Figs. 5 and 6.—More advanced stages of the decay, showing large central cavities filled by the fungus. More advanced condition than is shown in Plate IV. Natural size.

Plate VI. Late stages of the disease in stored tubers exposed to warm, dry air. Tubers shriveled and hard. Some free from surface mycelium. Others with masses of the fungus on the surface and in closed cavities.

Plate VII. A single colony of the fungus nine days old in a petri-dish culture on sugar-beet agar. Mycelium grown from a single spore.

Plate VIII. Drawings made with the aid of the camera lucida, showing development of the fungus. Fig. 1.—End of submerged hypha from the margin of a colony (see Pl. VII) on sugar-beet agar in a petri-dish culture, showing habit of growth and branching. × 108. Fig. 2.—End of submerged hypha from a colony similar to that shown in fig. 1. This hypha has begun to form microconidia, which may be seen on the end and on short lateral branches. × 108. Figs. 3–12.—Tip of a hypha from mycelium similar to that in figs. 1 and 2, showing in detail the formation of microconidia. The hypha is submerged in the agar and the microconidia remain in approximately the position in which they were formed. The time required for their formation may be judged from the appended figures, the hypha being under observation for several hours. × 324. Figs. 13–15.—Stages in the germination of a microconidium in sugar-beet agar in a Van Tieghem cell. In fig. 15 one cross-septum has been formed and several vacuoles have become visible. The spore was put into the germinating chamber at 10 a. m. and began to germinate much sooner than is usual. × 480. Figs. 16–19.—Part of a hypha growing in Uschinsky's fluid in a Van Tieghem cell, showing in detail stages in the formation of macroconidia on a swollen lateral branch. × 216. Figs. 20–22.—Stages in the germination of a macroconidium in

Uschinsky's fluid in a Van Tieghem cell. The spore was put into the germinating fluid at 10 a. m. × 480. Figs. 23–25.—Mature macroconidia grown in Uschinsky's fluid. Fig. 23 nearly straight; fig. 25 much curved. × 216. Fig. 26.—Part of hypha grown in beef bouillon, showing intercalary chlamydospores in stages of formation. × 135. Fig. 27.—Young chlamydospore borne on a short lateral branch, growing in beef bouillon. × 135. Fig. 28.—Young chlamydospore borne terminally on a long hypha, grown in beef bouillon. × 135. Fig. 29.—Mature chlamydospore grown in beef bouillon. × 480. Figs. 31–33.—Stages in the germination of a chlamydospore in beef bouillon in a Van Tieghem cell. The spore was put into the germinating fluid at 10 a. m., and began to germinate earlier than any of the others in the same medium. × 480. Fig. 34.—Tangential section through the vascular system of a diseased tuber, showing the long slender hypha, following a reticulate vessel and branching with it. × 110.

TEXT FIGURES.

Fig. 1.—Diagram of a longitudinal section of a potato. The dotted line marks the position of the vascular ring, and the lines across the main axis indicate the distances that the disease has progressed into this ring, designated in Table IV as "slight," "less than half," "half," "nearly all," and "all."

Fig. 2.—Diagram of potato field on Potomac Flats, Washington, D. C., in which (1902) the experiments were made with different fertilizers and different varieties with reference to resistance to the *Fusarium* disease. The lines represent the potato rows, and their intersections the hills. The numbers belong to the plots directly below them, and the fertilizers used and the varieties planted in them may be seen from Table I. The hills in which all the shoots showed the effect of the disease on July 27 are marked with a cross. Those in which only a part of the shoots was visibly affected are marked with an oblique line. The small plots planted to "Browns" are omitted for reasons already stated. There is a plantation road on the upper and right-hand sides of the field, bluegrass on the lower side, and Burbank potatoes of the same seed as that used in the experimental plots on the left-hand side. The ground slopes gently from the upper to the lower side of the field, as it appears on the page, and very slightly from left to right, but to the casual observer it would appear to be level.

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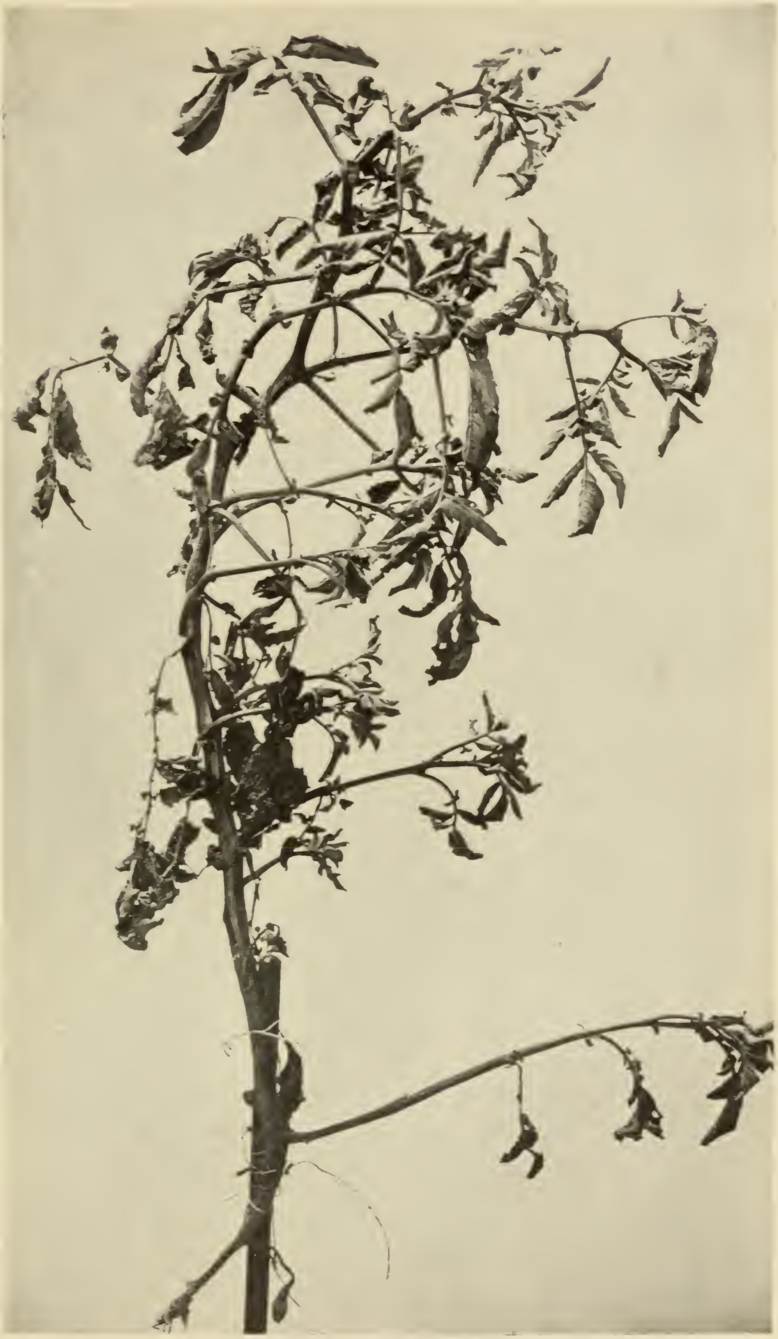
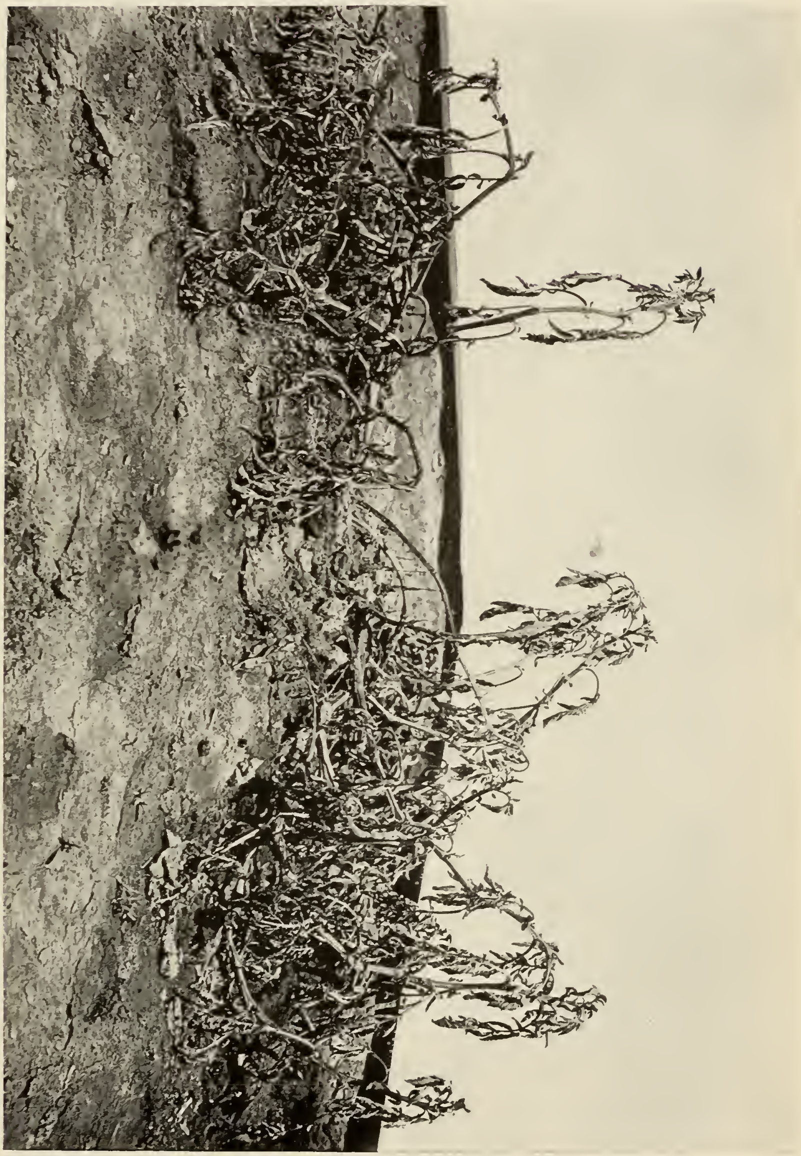
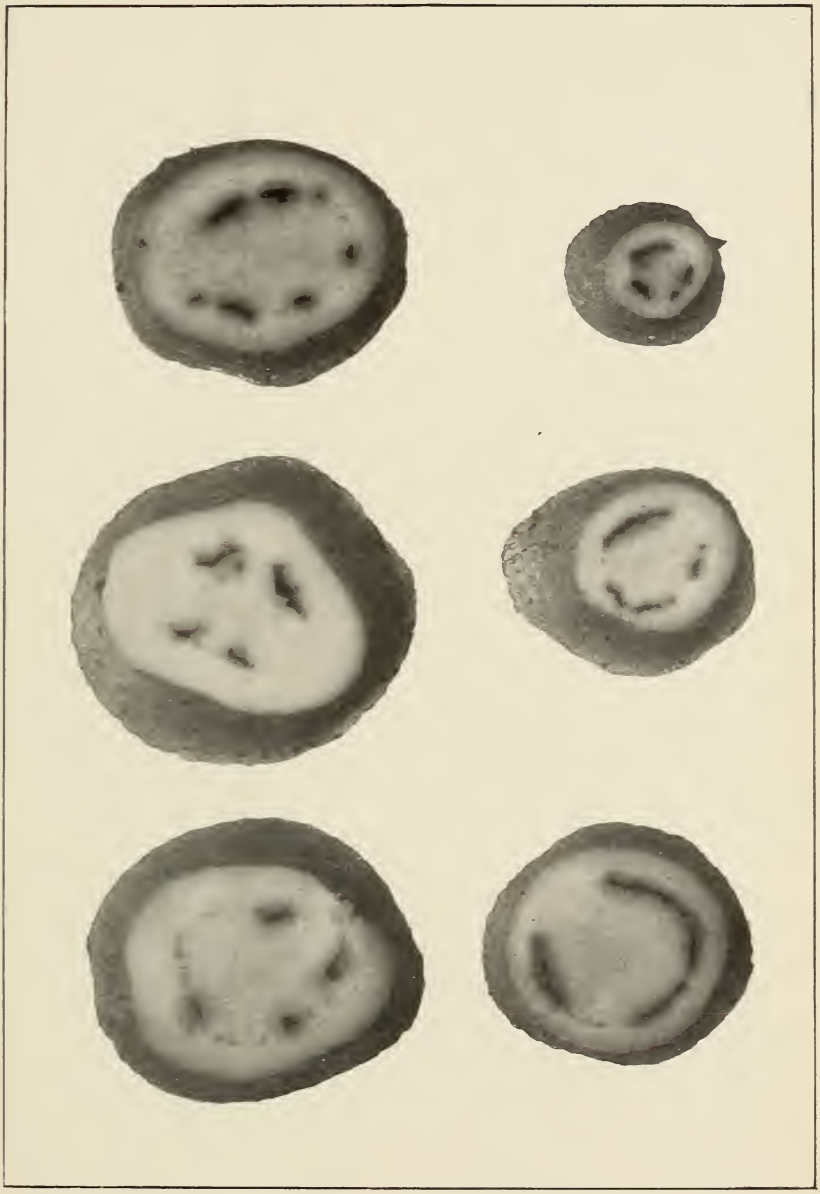


POTATO SHOOT ATTACKED BY FUSARIUM AND BEGINNING TO WILT.

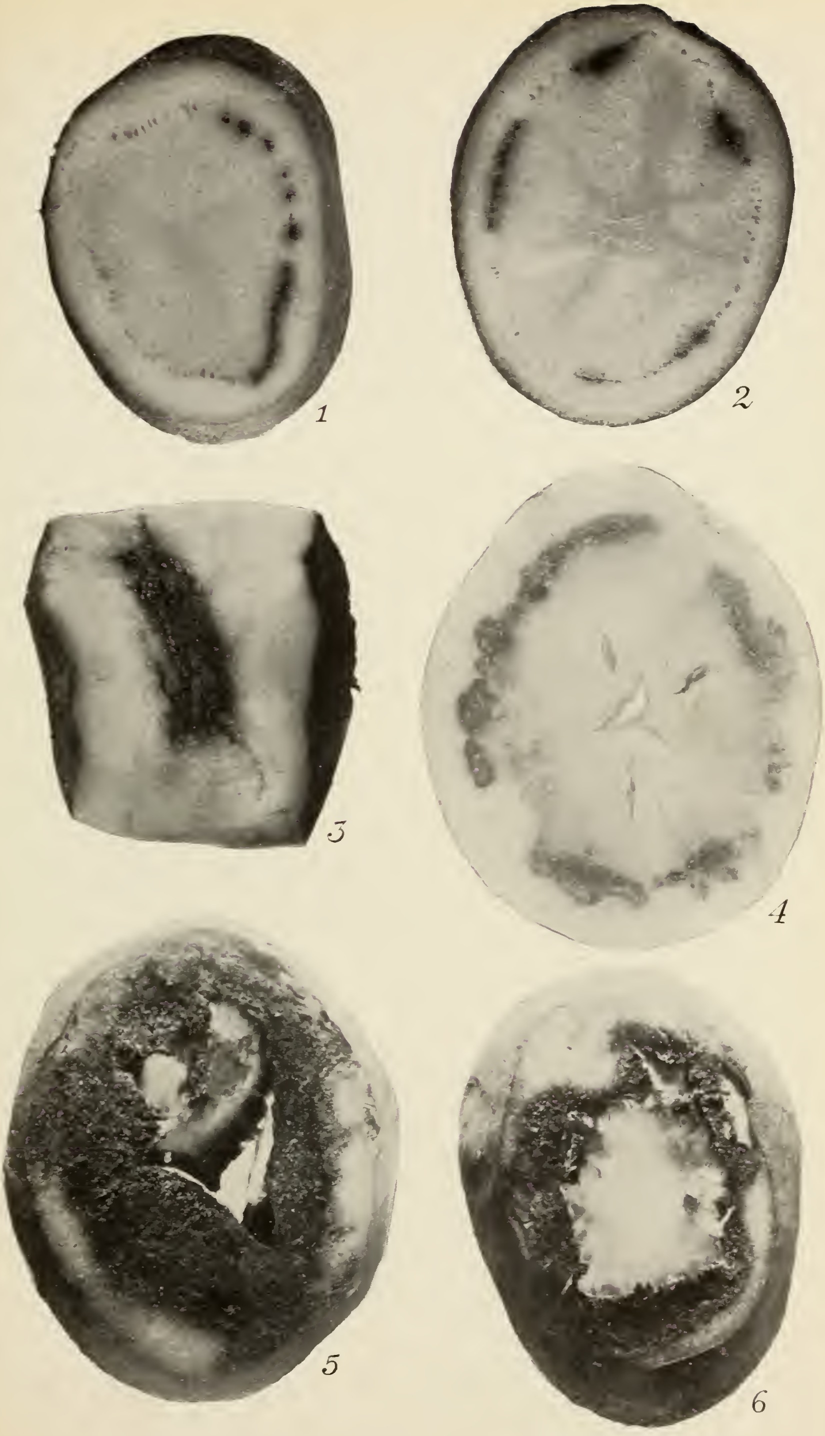


POTATO SHOOTS IN A LATER STAGE OF THE DISEASE.

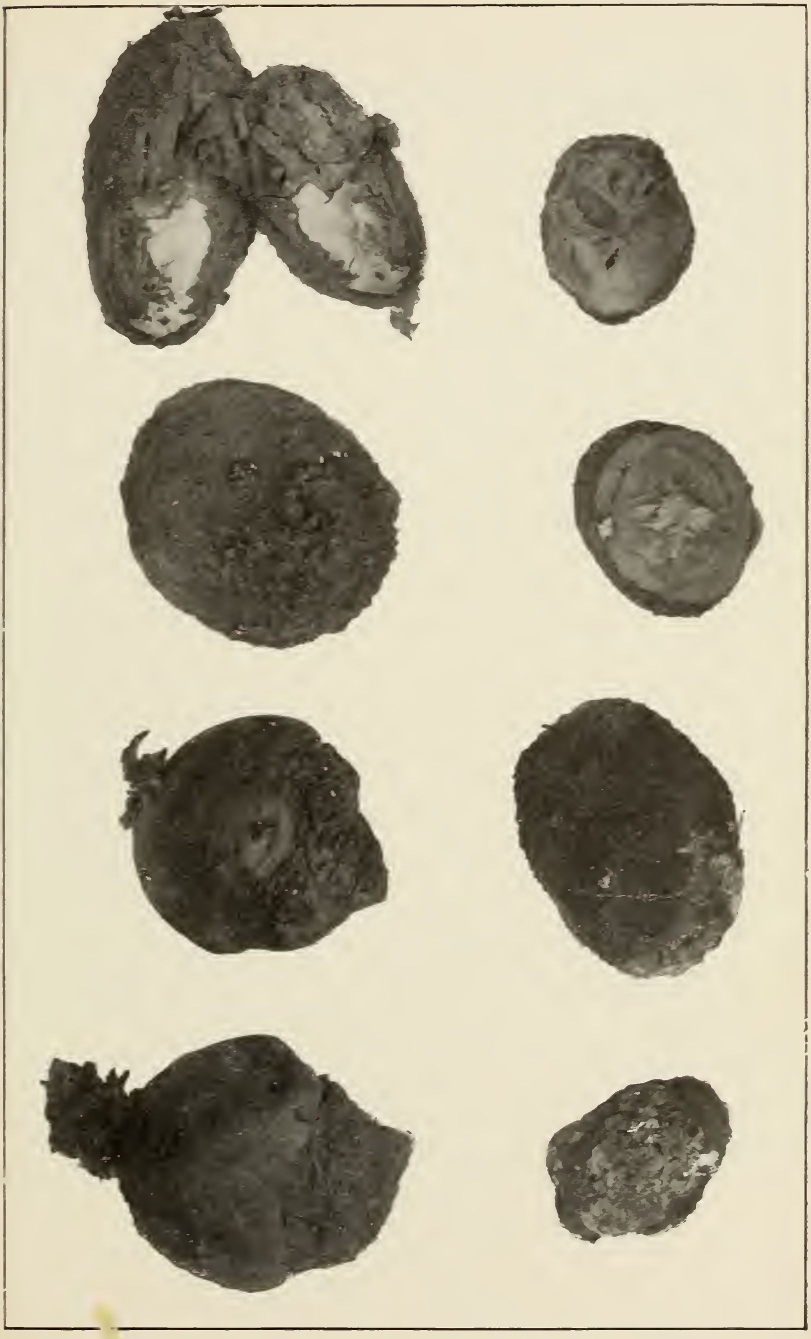


STEM END OF POTATO TUBERS, SHOWING BLACK STAIN IN VICINITY OF VASCULAR BUNDLES DUE TO PRESENCE OF THE FUSARIUM.

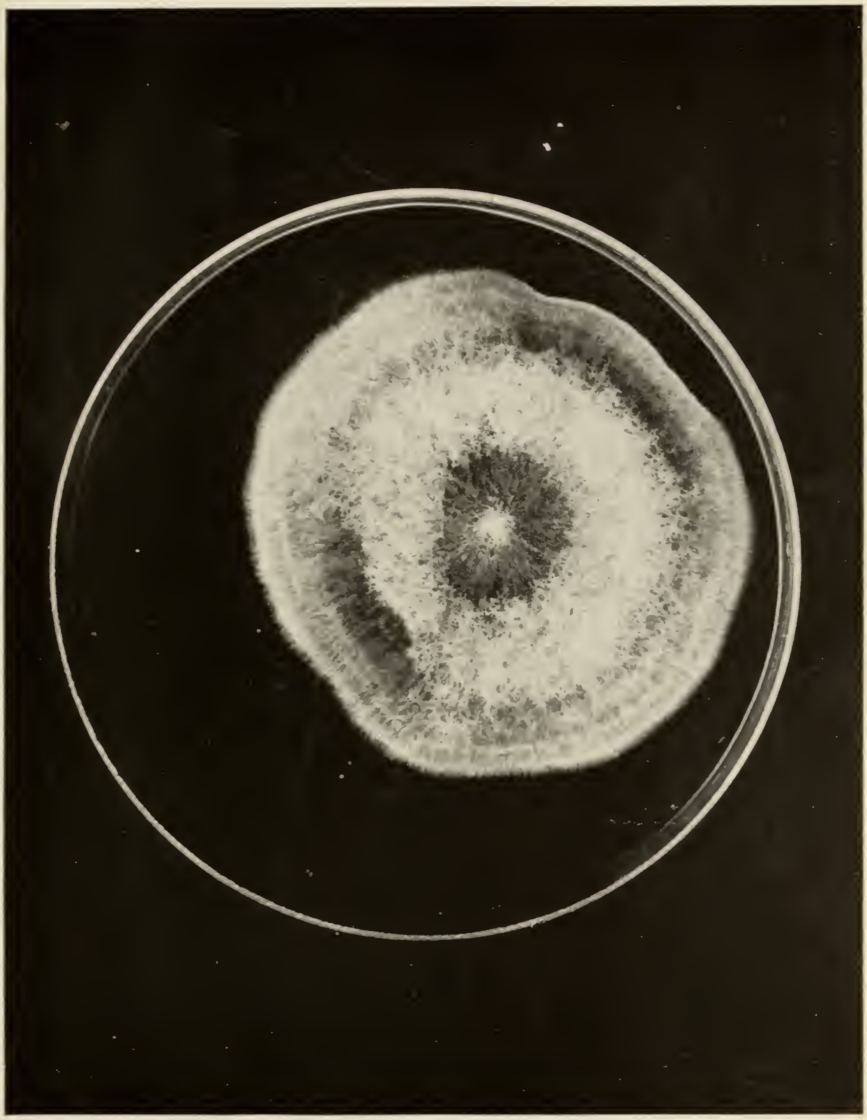
PLATE V.



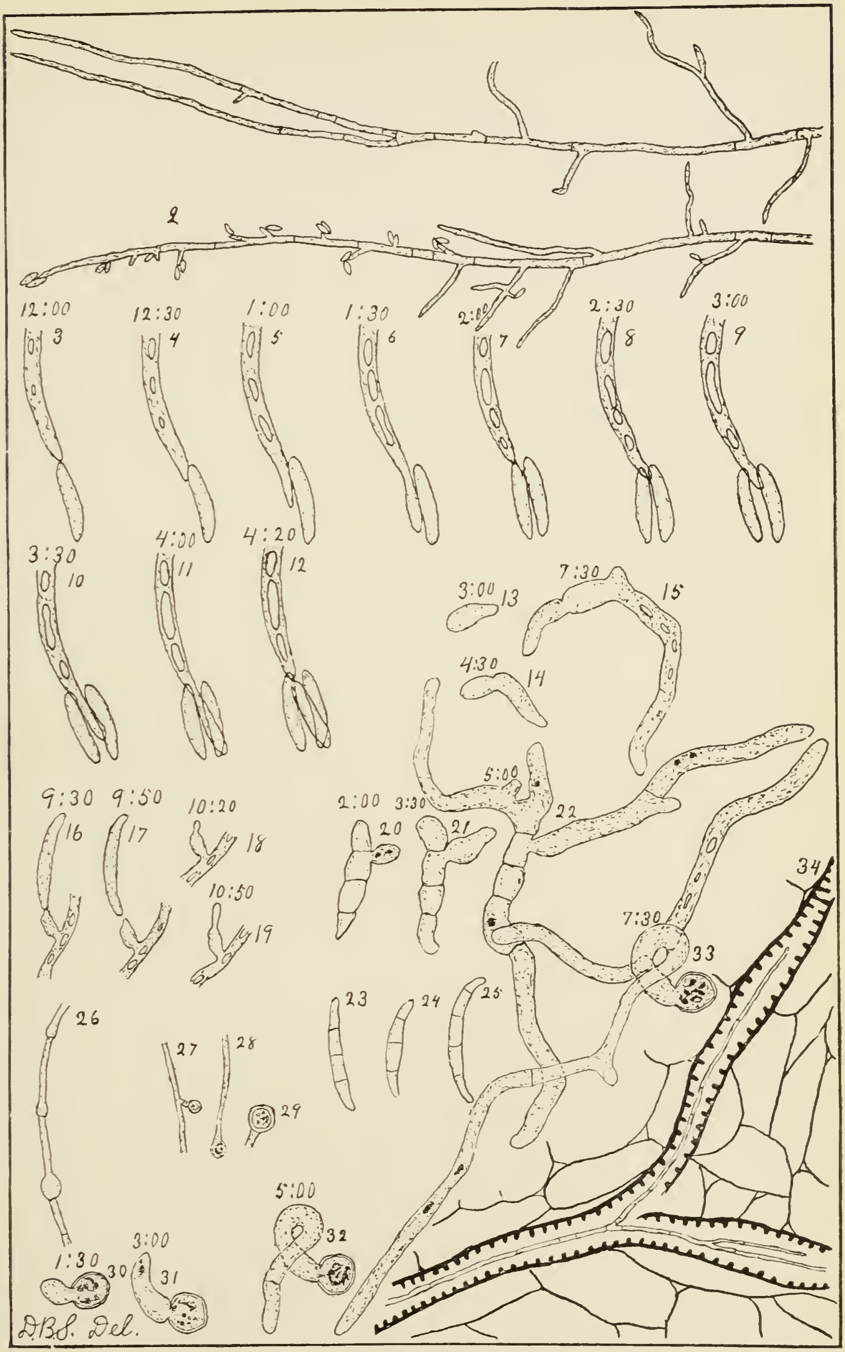
VARIOUS STAGES IN DESTRUCTION OF POTATO TUBERS BY FUSARIUM.



ACTION OF FUSARIUM ON POTATO TUBERS IN WARM, DRY AIR.



MYCELIUM OF THE POTATO FUSARIUM, GROWN FROM A SINGLE SPORE IN NUTRIENT AGAR.



MYCELIUM, SPORES, AND GERM TUBES OF THE POTATO FUSARIUM.

[Continued from page 2 of cover.]

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